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Your reference number: -

25 August 1999

Joint Steering Assembly
NPA Subscribers
JAA Regulation Advisory Panel

Re: NPA 25D-291 & NPA TSO-7 – Brakes and Braking Systems

The above NPA has been developed and is sponsored by the JAR D&F SG.

NPA Content

This NPA is based on the work done by the Brakes Harmonisation Working Group and parallels the equivalent NPRM (appended) published in the Federal Register on 10 August 1999 (NPRM 99-16 with comment period ending on 8 November 1999).

The package comprises a proposed revised JAR 25.731/735, a new AMJ 25.735 an a JTSO-C135 (in NPA JAR-TSO-7). A detailed explanatory note describes th proposed changes.

General

The NPA is the standard JAA procedure for consultation with the avia community. In addition to this JAA process the National Authorities may perform own consultation.

The objective of the NPA consultation is to inform interested parties of the c position and to receive comments on the draft. This means that the draft text necessarily the final text.

The JAA Committee expects that within the above perspective your organisation will participate efficiently in the NPA consultation. 'Your organisation is now invited to consider the NPA and to submit comments by **30 November 1999**. If no comments from your organisation by that date your agreement will be assumed.

Y Morier
Regulation Director

cc: P Mattei, SG Chairman
L Brunel, JAR-TSO SG Chairman

JOINT AVIATION AUTHORITIES

NOTICE OF PROPOSED AMENDMENT (NPA) COMMENT FORM
(See reverse side for guidelines)

1. **NPA NUMBER: NPA 25D-291**

Requirement paragraph...
ACJ/AMJ or AMC/IEM paragraph......

2. **POSITION (see 3.. on the reverse side)**

Agree / Accept / No comment.
Propose different text / general comment (see 3. below).
Propose to delete paragraph (see reverse side for explanation).

3. **PROPOSED TEXT/COMMENT**

Reason(s) for proposed text/comment

4. **ORGANISATION..**
Address ....

Telephone.. ....
Telefax.............

5. SIGNATURE ....

Date:

Name................

JAA Form 200

September 1995

Guidelines for the use of the NPA Comment Form

1.. This form should be seen as guidance material for cornmentors. Its, or any similar form's, use is not mandatory, but is useful for the expeditious examination of comments.

2.. If there is insufficient space on the form, use the blank space on this side or attachments.

3.. Cross out the parts of 2. that are not applicable.

In case of disagreement, cornmentors should be aware that failure to propose a text and explain the reason(s) for this text may well result in the comments being laid aside for lack of understanding. For the same reason, the commentor should explain a proposal to delete a paragraph.

4.. Commentors may copy this form or procure extra copies from JAA Headquarters

5.. All comments should be sent to the JAA Regulation Director at JAA Headquarters unless otherwise indicated in the NPA.

NPA 25D-291 ISSUE 1 DATED 6 JULY 1998

BRAKES AND BRAKING SYSTEMS

INTRODUCTION

The European Airworthiness Requirements for Large Civil Transport Aeroplanes contained in the Joint Aviation Requirements (JAR-25) are similar, but not identical to the requirements of the United States of America as published in Part 25 of the Federal Aviation Regulations. The need to establish compliance with both sets of requirements, can result in substantial additional costs to the industry, without necessarily providing any enhancement in safety. Therefore, recognising that a harmonised set of standards would not only benefit the aviation industry, but could also enhance safety levels, the European Joint Aviation Authority (JAA) and the US Federal Aviation Administration (FAA), with the co-operation of other organisations representing the European and American aerospace industries, began a process to harmonise their airworthiness requirements.

In 1992 the FAA harmonisation effort was undertaken by the Aviation Rulemaking Advisory Committee (ARAC) which was established to provide advice and recommendations concerning the full range of the FAA's safety-related rulemaking activities.

In co-operation and conjunction with ARAC, a Working Group comprised of brake and braking systems specialists from both Industry and National Aviation Regulatory Authorities was established. This Working Group was tasked with the development of new or revised harmonised requirements for brakes and braking systems installed in transport category aeroplanes, the associated testing requirements, any advisory or collateral documents or material as may be considered necessary, and the ultimate proposals for the amendment of both FAR part 25 and JAR-25.

Resulting from the deliberations of the Brakes and Braking Systems Harmonisation Working Group the FAA proposes to amend FAR Part 25 §§ 25.731 and 25.735, Amendment 25-72, as recommended by ARAC, and will in due course publish an NPRM (Notice of Proposed Rulemaking) in the Federal Register. This. and an associated Advisory Circular reference AC 25.735-1X, will be subjected to all the normal scrutiny and the public rulemaking procedures required by The Administrative Procedures Act of the United States.

Corresponding to the above US activities the JAA proposes this Notice of Proposed Amendment (NPA) to the Joint Aviation Requirements (JAR-25 Change 14).

In general terms it is proposed to add appropriate regulatory material, move some of the existing regulatory text into the advisory material, and to consolidate and/or separate existing regulatory material for clarity.

In conjunction with the above, the associated advisory material is provided by a new AMJ in place of the existing ACJs, in order to enhance the commonality with the intended FAA Advisory Circular (reference AC 25.735-1X). A new and harmonised Joint Technical Standard Order TSO-C135 ((J)TSO/TSO), based on the EUROCAE document ED 69 - Minimum Operational Performance Specification for Wheels and Brakes on JAR-25 Civil Aeroplanes, will also be published.

The following contains 19 separate proposals and presents the details of, and the justifications for, the proposed amendment to the requirements of JAR-25 paragraphs 25.731 and 25.735. This is followed by the text for the new JAR 25.735, new sub-paragraphs 25.731(d) and (e), and the associated advisory material.

PROPOSALS

Proposal 1

The JAA proposes to change the heading "JAR 25.735 Brakes" to "JAR 25.735 Brakes and Braking Systems".

Discussion

This paragraph covers not only the brakes and their performance requirements and safety considerations, but also provides requirements for the systems and equipment associated with the brakes. As examples, JAR-25 Change 14 sub-paragraph 25.735(b) refers to "The brake system and associated systems . . . . ", the proposed sub-paragraphs 25.735(b)(2) refers to the hydraulic brake system and the hydraulic fluid supplying the brakes, and sub-paragraph 25.735(e) refers to the antiskid system. The proposed change is introduced solely to make the paragraph heading more representative of the paragraph content, is of an editorial nature only, and consequently would have no impact on the current level of safety.

Proposal 2

The JAA proposes to introduce the heading "Approval" to sub-paragraph 25.735(a) of this paragraph. The JAA also proposes to amend the current JAR 25.735(a) to read "Each assembly, consisting of a wheel(s) and brake(s), must be approved."

Discussion

The current JAR 25.735(a), which states that "Each brake must be approved" is inadequate. Although a wheel not associated with a brake (non-braked) may be approved on its own using the applicable standards (usually an FAA Technical Standard Order) (TSO)), a brake approval is always considered in combination with its associated wheel(s) (i.e. for a combined wheel(s) and brake(s) assembly). The proposed change is of an editorial nature only and would have no impact on the current level of safety.

Applicable advisory information would be included in the proposed new AMJ 25.735.

Proposal 3

The JAA proposes to add the heading "Brake System Capability" to JAR 25.735(b), to separate and revise the current text' of the first sentence of JAR 25.735(b) into JAR 25.735(b) and (b)(1) and to delete the entire second sentence to read, "(b) *Brake System Capability*. The brake system, associated systems and components must be designed and constructed so that:-
(1) If any electrical, pneumatic, hydraulic or mechanical connecting or transmitting element fails, or if any single source of hydraulic or other brake operating energy supply is lost, it is possible to

bring the aeroplane to rest with a braked roll stopping distance of not more than two times that obtained in determining the landing distance as prescribed in JAR 25.125".

Discussion

The current text of the first sentence of JAR 25.735(b) reads, "The Brake systems and associated systems must be designed and constructed so that if any electrical, pneumatic, hydraulic, or mechanical connecting or transmitting element (excluding the operating pedal or handle) fails, or if any single source of hydraulic or other brake operating energy supply is lost, it is possible to bring the aeroplane to rest under conditions specified in JAR 25.125 with a mean deceleration during the landing roll of at least 50% of that obtained in determining the Landing distance as prescribed in that paragraph".

Under this proposal, the term "components" would be added to the terms "brake system and associated systems" to make the paragraph more comprehensive. The parenthetical phrase "(excluding the operating pedal or handle)" would be deleted because no justification could be found for such an exclusion. The words "braked roll stopping distance" would be inserted in place of "landing roll" to clarify that the requirement refers only to the distance covered while the brakes are applied. The change from "at least 50% mean deceleration" to "not more than two times the landing distance" is intended to eliminate any possible confusion between "mean" and "average" deceleration, and to state the requirement more clearly in terms of its real intent. The other changes are editorial and are made for clarity.

The current second sentence reads "Sub-components within the brake assembly, such as brake drum, shoes and actuators (or their equivalents), shall be considered as connecting or transmitting elements, unless it can be shown that leakage of hydraulic fluid resulting from failure of the sealing elements in these sub-components within the brake assembly would not reduce the braking effectiveness below that specified in this sub-paragraph". This sentence would be removed and, due to its advisory content, would be included in the proposed new AMJ 25.735.

The proposed changes are clarifications of current regulations and the associated terminology and therefore would have no impact on the current level of safety.

Applicable advisory information would be included in the proposed new AMJ 25 735

Proposal 4

The JAA proposes to introduce a new sub-paragraph JAR 25.735(b)(2) that would contain the intent of the content of the current ACJ 25.735(b) regarding the protection against fire resulting from hydraulic fluid leakage, spillage or spraying onto hot brakes. The proposal would state " (2) Fluid lost from a brake hydraulic system, following a failure in, or in the vicinity of, the brakes, is insufficient to cause or support a hazardous fire on the ground or in flight".

Discussion

Although the proposed requirement was previously included in ACJ 25 735(b) as acceptable means of compliance and interpretative material, it is now thought more appropriate that these practices should be considered as requirements as they have generally been treated as such in the past by both aeroplane manufacturers and regulatory authorities. The current level of safety would not be affected by the proposed change because it would adopt an existing industry practice.

Applicable advisory material would be included in the proposed new AMJ 25.735.

Proposal 5

The JAA proposes to introduce the heading "Brake controls" to sub-paragraph 25.735(c) of this paragraph, and to separate and revise the current text of the JAR 25.735(c) into JAR 25.735(c) and (c)(1) to read " (c) *Brake Controls.* The brake controls must be designed and constructed so that:- (1) Excessive control force is not required for their operation",

Discussion

The current text reads, "Brake controls may not require excessive control force in their operation." The proposed changes are clarifications of current regulations and the associated terminology and therefore the current level of safety would not be impacted.

Applicable advisory material, including the current advisory material which refers to the progressive nature of the control forces and to the allowable exception to this principle for controls solely and separately provided for the operation of parking brakes, would be included in the proposed new AMJ 25.735.

Proposal 6

The JAA proposes to add a new sub-paragraph 25.735(c)(2) to read "(2) If an automatic braking system is installed, means are provided to: (i) arm and disarm the system, and (ii) allow the pilot(s) to override the system by use of manual braking".

Discussion

The intent and content of the proposed changes have generally been adopted in the design of current automatic braking systems and are currently included in the FAA Order 8110.8, "Engineering Flight Test Guide for Transport Category Airplanes" as interpretative material and acceptable means of compliance. Consequently, both the aeroplane manufacturers and the regulatory authorities have generally considered them as standard practices and therefore would not impact the current level of safety.

Applicable advisory material would be included in the proposed new AMJ 25.735.

Proposal 7

The JAA proposes to amend the current sub-paragraph 25.735(d) by adding the heading "Parking Brake" and by modifying the current text from "The aeroplane must have a parking control that, when set by the pilot, will without further attention, prevent the aeroplane from rolling on a paved, level runway with take-off power on the critical engine." to "The aeroplane must have a parking brake control that, when selected on, will without further attention, prevent the aeroplane from rolling on a dry and level paved runway when the most adverse combination of maximum thrust on one engine and up to maximum ground idle thrust on any, or all, other engine(s) is applied. The control must be suitably located or be adequately protected to prevent inadvertent operation. There must be indication in the cockpit when the parking brake is not fully released".

Discussion

Introduction of the word "brake" before "control" clarifies that the sub-paragraph refers to the means provided to the flight crew for the application of the wheel brakes in the aeroplane parking mode..By revising the text as proposed the requirement would be enhanced to cover not only the case of a single engine take-off power check with all other engines stopped, but would also cover an equally if not more probable case where any or all other engines are operating and producing up to a minimum level of forward thrust. The proposal also clarifies the extent of the take-off thrust to be considered for the "critical" engine as the maximum which can be achieved, and by implication also requires the relevant thrust cases for remaining engine(s) according to the environmental circumstances that are dictated for the achievement of the maximum take-off thrust on the critical engine. The word "dry" is added solely for clarification of the current understanding of this requirement.

The requirement for suitable location or protection against inadvertent operation of the parking brake control is derived from the current ACJ 25.735(d) and is introduced because it is believed that such considerations should be regarded as requirements, and have generally been treated as such in the past by both aeroplane manufacturers and regulatory authorities The additional requirement for cockpit indication that the parking brake is "not fully released" is to alert the pilot to the brake being set, or partially set., prior to towing, taxiing, take-off or even landing manoeuvres. The proposed changes potentially enhance the current level of safety by clarifying the intent and addressing some critical cases.

Applicable advisory material would be included in the proposed new AMJ 25.735.

Proposal 8 (In association with Proposals 9 & 10)

The JAA proposes to add the heading "Antiskid System" to sub-paragraph JAR 25.735(e), to delete the current text "no single probable malfunction will result in a hazardous loss of braking ability or directional control of the aeroplane", and revise the remaining current text to read: "(e) *Antiskid System.* If an anti-skid system is installed:- ..."

Discussion

The current sub-paragraph (e) reads "If anti-skid devices are installed, the devices and associated systems must be designed so that no single probable malfunction will result in a hazardous loss of braking ability or directional control of the aeroplane. (See ACJ 25.735(e))". The reference to "Antiskid devices and associated systems" would be changed to "Antiskid systems"; this being more appropriate to the sub-paragraph's intent. The term "probable"' was incompatible with the terminology of JAR 25.1309 because a "probable" malfunction cannot be associated with either major or hazardous effects and, if used in the "25.1309" sense, could lead to a requirement that could be seen as less severe than JAR 25.1309 for that specific failure condition, with no obvious technical/state of the art reasons. It appears that the terminology (probable and hazardous) used was "probably" not "25.1309 related" when the requirement was first introduced. Rather than trying to define the words, it is considered that the requirement is adequately covered by JAR 25.1309 and that the current JAR 25.735(e) is superfluous. The proposed changes are of a clarifying and editorial nature only, and therefore would have no impact on the current level of safety.

Appropriate advisory material would be included in the proposed new AMJ 25.735.

Proposal 9

The JAA proposes to add a new sub-paragraph JAR 25.735(e)(1) to read "(1) It must operate satisfactorily over the range of expected runway surface conditions, without external adjustment. ".

Discussion

The intent and content of the proposed changes are currently included in FAA Order 8110.8, "Engineering Flight Test Guide for Transport Category Airplanes", as interpretative material and acceptable means of compliance and are deemed appropriate to be adopted as requirements. Both the aeroplane manufacturers and the regulatory authorities have, in the past, considered them as standard practices and therefore would not impact the current level of safety.

Applicable advisory material would be included in the proposed new AMJ 25.735.

Proposal 10

The JAA proposes to add a new sub-paragraph JAR 25.735(e)(2) to read "(2) It must, at all times, have priority over the automatic braking system, if installed".

Discussion

The intent and content of the proposed additional requirement are currently included in FAA Order 8110.8, "Engineering Flight Test Guide for Transport Category Airplanes", as interpretative material and acceptable means of compliance and are deemed appropriate to be adopted as requirements. Both the aeroplane manufacturers and the regulatory authorities have, in the past, considered them as a standard practices and therefore would not impact the current level of safety.

Applicable advisory material would be included in the proposed new AMJ 25.735.

Proposal 11

(Note: This item proposes changes to amendments proposed in NPA 25B,D,G-244, Accelerate -Stop Distances and Related Performance. Publication of that amendment is expected soon. In the event that this rulemaking should precede the above to publication, this proposal would need to be rewritten to address the current JAR/FAR.)

The JAA proposes to amend the current sub-paragraph JAR 25.735(f) by adding the heading "Kinetic Energy Capacity", by consolidating the requirements of the current sub-paragraphs JAR 25.735(f) and JAR 25.735(h), by adding similar requirements for a high energy landing condition, and by specifying the substantiation means. The text would be revised to read:

"(f) *Kinetic Energy Capacity* The design landing stop, the maximum kinetic energy accelerate-stop, and the most severe, landing stop brake kinetic energy absorption requirements of each wheel and brake assembly must be determined. It must be substantiated by dynamometer testing that, at the declared fully worn limit(s) of the brake heat sink, the wheel and brake assemblies are capable of absorbing not less than these levels of kinetic energy. Energy absorption rates defined by the aeroplane manufacturer must be achieved. These rates must be

equivalent to mean decelerations not less than 10 ft/s^2 for the design landing stop and 6 ft/s^2 for the maximum kinetic energy accelerate-stop.
The design landing stop is an operational landing stop at maximum landing weight.
The maximum kinetic energy accelerate-stop is a rejected take-off at the most critical combination of aeroplane take-off weight and speed.
The most severe landing stop is a stop at the most critical combination of aeroplane landing weight and speed. The most severe landing stop need not be considered for extremely improbable failure conditions or if the maximum kinetic energy accelerate-stop energy is more severe."

Discussion

The current sub-paragraphs (f) and (h) state that the brake kinetic energy capacity ratings may not be less than the determined energy absorption requirements. The proposed sub-paragraph JAR 25.735(f) would require the calculation of the necessary energy absorption capacity of each wheel and brake assembly, and would also require dynamometer test substantiation of the capability of the wheel and brake assemblies to absorb the energy at not less than specified rates. Usually, brakes are sized to exceed the calculated energy absorption requirements (i.e. their capacity exceeds the requirements, hence the heading "Kinetic Energy Capacity"). The term "rating" would be deleted because it is more relevant to compliance with sub-paragraph JAR 25.735(a) and (J)TSO C-135 than the regulation. The proposed changes would encompass the requirements of the current sub-paragraph JAR 25.735(h) without the need for extensive duplication of the text.

The term "rejected take-off' used in the current sub-paragraph JAR 25.735(h) would&e replaced by "accelerate-stop" for compatibility with JAR 25.109 terminology, and the term "most severe landing stop" would be added to address the cases such as an emergency return to land after take-off, where the brake energy for a flaps up landing may exceed that of a maximum kinetic energy accelerate-stop. It is intended that for the accelerate-stop and the most severe landing stop the initial brake temperature resulting from previous brake use must be accounted for as specified in paragraphs 3.3.3.3 and 3.3.4.3 in the proposed (J)TSO-C 135. It should be noted that the consideration for the initial brake temperature (in terms of residual energy) reflects an existing British Civil Aviation Authority (CAA) Specification 17 requirement.

Changing the term "main wheel-brake assembly" to "wheel and brake assembly" ensures the paragraph's applicability to any wheels fitted with brakes (i.e. includes the possibility of' nose wheel brakes etc.) and further ensures the understanding that the energy absorption requirements apply to each wheel and brake assembly. The substantiation statement would require that the wheel and brake assemblies be capable of absorbing the calculated levels of kinetic energy at the heat sink's fully worn limit and that the energy absorption capability substantiation testing be conducted on a dynamometer.

The current sub-paragraphs 25.735(f)(1) and (h)(l), and sub-paragraphs 25.735(f)(2) and (h)(2) would be incorporated into the proposed AMJ 25.735 because their content is not strictly part of the requirement but provides advice on the method of energy calculation to be used and primary features that must be conservatively included in a rational analysis.
Because the required kinetic energy capacity of <u>each</u> wheel and brake assembly must be determined, the need to refer to "unequal braking distributions" is no longer necessary and would be deleted.

The current level of safety would be retained and possibly enhanced by addressing the most severe landing stop condition.

Applicable advisory material would be included in the proposed new AMJ 25.735.

Proposal 12

The JAA proposes to remove the current sub-paragraph JAR 25.735(g).

Discussion

The current JAR 25.735(g) states that when setting up the dynamometer test inertia, an increase in the initial brake application speed is not a permissible method of accounting for a reduced (i.e. lower than ideal) dynamometer mass. This method is not permissible because, for a target test deceleration, a reduction in the energy absorption rate would result, and could produce a performance different from that which would be achieved with the correct brake application speed. Such a situation is recognised and is similarly excluded in the proposed new (J)TSO-C 135 which would provide an acceptable means for wheel and brake assembly approval against sub-paragraph JAR 25.735(a), thus making the current sub-paragraph JAR 25.735(g) unnecessary. The proposed change consolidates existing requirements and deletes redundant wording only, and therefore would not impact the current level of safety.

Proposal 13

The JAA proposes to add a new sub-paragraph JAR 25.735(g) with the heading "Brake condition after high kinetic energy dynamometer stop(s)" to read, "Following the high kinetic energy stop demonstration(s) required by sub-paragraph (f) of this paragraph, with the parking brake promptly and fully applied for at least three (3) minutes, it must be demonstrated that for at least five (5) minutes from application of the parking brake, no condition occurs (or has occurred during the stop), including fire associated with the tyre or wheel and brake assembly, that could prejudice the safe and complete evacuation of the aeroplane."

Discussion

The proposed new sub-paragraph JAR 25.735(g) would require the parking brake to be promptly and fully applied for at least three minutes without specifying the level of effectiveness to be demonstrated, due to the practicalities of such a demonstration. Three minutes is considered to be the minimum period of time to cover the brake's ability to maintain the aeroplane in a stationary condition to allow a safe evacuation.

The requirement also gives consideration to the fact that the flight crew may not be aware of the condition of the brake assemblies at the commencement of the flight, nor of the condition of the brake and wheel assemblies following the braking manoeuvre. Furthermore, the reason for the severe braking could encompass both aeroplane system and engine failure or fires. It would therefore appear sensible that it should be demonstrated that neither during the stop, nor for a reasonable period after its completion, no condition(s) occurs as a result of these manoeuvres that could further prejudice the safe and complete evacuation of the aeroplane. On the basis that an evacuation may be determined as prudent or necessary, and that such an evacuation must be capable of completion, irrespective of the timely response of the emergency services, five minutes would appear to be a reasonable period for the associated brake systems and equipment to remain free from conditions that might prejudice or jeopardise the evacuation. It is proposed that this five minute period would commence at the time of initial application of the parking brake; this being when a possible need for the attendance of airport emergency services occurs following an accelerate-stop. The proposed changes provide for the additional demonstration of a safe condition following high energy absorption by the wheels and brakes, which was not previously required. Although previously approved brakes may have been able to comply with the requirement, approval could not have been refused had this not been the case. It is therefore believed that the proposed changes would provide a potential enhancement of the current level of safety.

Applicable advisory material would be included in the proposed new AMJ 25.735.

Proposal 14

The JAA proposes to amend the current sub-paragraph JAR 25.735(i) and to introduce this as a new sub-paragraph JAR 25.735(h), with the preceding heading "Stored energy systems" to read, " An indication to the flight crew of usable stored energy must be provided if a stored energy system is used to show compliance with sub-paragraph (b)(l) of this paragraph. The available stored energy must be sufficient for:-

(1) At least six (6) full applications of the brakes when an anti-skid system is not operating, and

(2) Bringing the aeroplane to a complete stop when an anti-skid system is operating, under all runway surface conditions for which the aeroplane is certificated. "

Discussion

For those aeroplanes that may provide a number of independent braking systems perhaps incorporating a stored energy device, but are not "reliant" on the stored energy system for the demonstration of compliance with sub-paragraph (b)(1) of this paragraph, this requirement would not be applicable. It would be unreasonable that the requirement for a minimum energy storage capacity and the provision of means to indicate the level of stored energy to the flight crew should be maintained, particularly if failure of either would have a minimal consequence on aeroplane or passenger safety.

In the event that an hydraulic accumulator is used for energy storage and the gas pressurisation is incorrectly maintained, a pressure indication alone (as currently required by JAR 25.735 (i)), would be inadequate because it would not provide indication of such a fault to the flight crew. In fact the current typical flight deck presentation could give a false sense of security to the crew because it would almost inevitably indicate a satisfactory pressure, regardless of the real situation. Consequently, the proposed rule would require a measure of the stored energy, rather than pressure, to be presented to the flight crew.

The minimum level of stored energy required for the emergency/standby braking means would be presented as a requirement rather than as advisory material. In the majority of cases, this material has been used as a virtual requirement in the past by aeroplane manufacturers and regulatory authorities. The proposed change would potentially enhance current safety levels because the JAA is proposing to adopt a common but not universal industry practice and an improvement over the existing JAR rule.

Applicable advisory material would be included in the proposed new AMJ 25.735.

Proposal 15

The JAA proposes to add a new sub-paragraph JAR 25.735(i) with the preceding heading *"Brake wear indicators"* to read, "Means must be provided for each brake assembly to indicate when the heat sink is worn to the permissible limit. The means must be reliable and readily visible."

Discussion

In order to ensure, as far as is practicable, that each brake heat sink is not worn beyond its allowable wear limit throughout its operational life, it is considered necessary to provide some device that can readily identify the fully worn limit of the heat sink. The proposal reflects a requirement included in a series of FAA airworthiness directives (FAA ADs) issued between 1989 and 1994 to require the establishment of brake wear limits and to provide means to indicate the same, for the then existing US registered fleet of transport category aeroplanes, in compliance with the associated National Transportation Safety Board (NTSB) recommendation number A-88-075. CAA Specification No 17 also specifies the provision of such an indicator and the majority of wheel and brake assembly designs include such a device. The proposed rule would have no impact on the current level of safety because the JAA is proposing to adopt an existing industry practice.

Appropriate advisory material would be provided in the proposed new AMJ 25.735.

Proposal 16

The JAA proposes to add a new sub-paragraph JAR 25.735(j) with the preceding heading "*Overtemperature **burst** prevention*" to read, "Means must be provided in each braked wheel to prevent wheel failure and tyre burst that may result from elevated brake temperatures. Additionally, all wheels must meet the requirements of JAR 25.731(d)".

Discussion

There is an existing requirement (JAR 25.729(f)) related to the protection of equipment on the landing gear and in wheel wells against the effects of bursting tyres and possible wheel brake temperatures. Similar texts are to be found in the "Minimum Operational Performance Specification for Wheels and Brakes on JAR part 25 Civil Aeroplanes" (EUROCAE document ED-69) and in TSO-C26c (Wheels and Brakes) and in (J)TSO-C62d (Tyres). However, there is no direct requirement in JAR-25 or in 14 CFR part 25 that such means must be provided to prevent wheel failure and tyre burst that could result from elevated brake temperatures. As a result, it has become an industry practice to incorporate pressure release device(s) that function as a result of elevated wheel temperatures to deflate the tyres. Nevertheless, it is believed to be both reasonable and prudent that such a requirement should be clearly stated in the paragraph related to aeroplane brakes and braking systems. The proposed requirement for temperature activated devices would not impact the current level of safety.

Applicable advisory material would be provided in the proposed new AMJ 25.735.

Proposal 17

The JAA proposes to add a new sub-paragraph JAR 25.735(k) with the preceding heading "*Compatibility*" to read, " Compatibility of the wheel and brake assemblies with the aeroplane and its systems must be substantiated."

Discussion

Reliable and consistent brake system performance can be adversely affected by incompatibilities within the system and with the landing gear and aeroplane. As part of the overall substantiation of safe and anomaly free operation it is necessary to show that no unsafe conditions arise from incompatibilities between the brakes and braking system and other aeroplane systems and structures. Areas such as antiskid tuning, landing gear dynamics, tyre type and size, brake combinations, brake characteristics, brake and landing gear vibrations, etc., need to be explored and corrected if necessary.
Therefore, this requirement is introduced to address these issues which are normally covered by the aeroplane manufacturer during the development of the aeroplane, and must be similarly addressed by modifiers of the equipment. Incorporation of this requirement would potentially enhance current levels of safety.

Appropriate advisory material would be provided in the proposed new AMJ 25.735.

Proposal 18

The JAA proposes to add a new sub-paragraph JAR 25.731(d) with the preceding heading "*Overpressure burst prevention*" to read, "Means must be provided in each wheel to prevent wheel failure and tyre burst that may result from excessive pressurisation of the wheel and tyre assembly."

Discussion

Wheel failure and tyre burst due to overinflation presents a hazard to ground personnel and the aeroplane. Some aeroplane manufacturers and some wheel manufacturers require pressure release devices that reduce this hazard. This is considered to be a safety issue requiring the incorporation of such a device(s) in each wheel. Incorporation of pressure release devices in tyre inflation equipment is not considered adequate, due to a history of misuse resulting in serious injuries and fatalities. Their installation in the wheel is believed to reduce the potential for tampering and misuse, and to ensure as far as is practicable, proper levels of protection. Introduction of this requirement would maintain and potentially enhance current levels of safety.

Applicable advisory material would be provided in the proposed new AMJ 25.735.

Proposal 19

The JAA proposes to add a new sub-paragraph JAR 25.731(e) with the preceding heading "*Braked Wheels*" to read, "Each braked wheel must meet the applicable requirements of JAR 25.735."

Discussion

JAR 25.731 contains regulations applicable to all aeroplane wheels. If the wheel is braked, additional regulations also apply which are contained in JAR 25.735. This sub-parrgraph is added to provide a cross-reference to those additional requirements. The proposed change would maintain and potentially enhance the current level of safety.
(Advisory material related to this rule would not be provided because it is believed to be self explanatory).

ECONOMIC IMPACT EVALUATION/ASSESSMENT

The JAA estimation is that only proposal 11 would result in incremental costs attributable to the subject NPA. Demonstrating adherence to the "most severe landing stop" MSL requirement would increase nonrecurring testing costs from 20,000 to 60,000 ECU for a JAR-25 type of aeroplane, with cost increasing with the size of the aeroplane. This cost corresponds to the equivalent of two additional high energy dynamometer tests in which the test brake would be destroyed. Cost savings from harmonisation, in terms of avoiding added costs of co-ordination and documentation, with the FAA and involving' for example, additional travel overseas, reports, etc., would be equal to or greater to the maximum cost of 60,000 ECU. The JAA believes that potential safety benefits resulting from specification of minimum accepted standards would supplement these cost-savings. Although there were numerous (approximately 170) accidents involving brake failures during landings in the period 1982-1995, none where determined to have been directly preventable by the subject provisions. Different designs in future certifications, however could present unexpected problems and raise future accident rates. This proposed requirement is expected to reduce the chances of future accidents by codifying in the JAR and therefore making mandatory what was prevailing, but not necessarily universal, industry practice. For those reasons, the JAA finds the proposed requirement to be cost-beneficial.

PROPOSED NEW **REQUIREMENTS** AND ADVISORY MATERIAL

JAR-25 SECTION 1
SUBPART D - DESIGN AND CONSTRUCTION
LANDING GEAR

JAR-25 The text of the JAR-25 Paragraphs JAR 25.731 and JAR 25.735 would be amended to read as follows:-

JAR 25.73 1 Wheels

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(d) *Overpressure burstprevention.* Means must be provided in each wheel to prevent wheel failure and tyre burst that may result from excessive pressurisation of the wheel and tyre assembly.

(e) *Braked wheels.* Each braked wheel must meet the applicable requirements of JAR 25.735.

JAR 25.735 Brakes and Braking Systems
(See AMJ 25.735)

(a) *Approval.* Each assembly, consisting of a wheel(s) and brake(s), must be approved.

(b) *Brake System Capability.* The brake system, associated systems and component; must be designed and constructed so that:-

(1) If any electrical, pneumatic, hydraulic or mechanical connecting or transmitting element fails, or if any single source of hydraulic or other brake operating energy supply is lost, it is possible to bring the aeroplane to rest with a braked roll stopping distance of not more than two times that obtained in determining the landing distance as prescribed in paragraph JAR 25.125.

(2) Fluid lost from a brake hydraulic system, following a failure in, or in the vicinity of, the brakes, is insufficient to cause or support a hazardous fire on the ground or in flight.

(c) *Brake controls.* The brake controls must be designed and constructed so that:-

(1) Excessive control force is not required for their operation.
(2) If an automatic braking system is installed, means are provided to:-
(i) arm and disarm the system, and
(ii) allow the pilot(s) to override the system by use of manual braking.

(d) *Parking Brake.* The aeroplane must have a parking brake control that, when selected on, will, without further attention, prevent the aeroplane from rolling on a dry and level paved runway when the most adverse combination of maximum thrust on one engine and up to maximum ground idle thrust on any, or all, other engine(s) is applied. The control must be suitably located or be adequately protected to prevent inadvertent operation. There must be indication in the cockpit when the parking brake is not fully released.

(e) Antiskid System If an anti-skid system is installed-

(1) It must operate satisfactorily over the range of expected runway conditions without external adjustment.

(2) It must, at all times, have priority over the automatic braking system (if installed).

(f) ***Kinetic Energy Capacity.*** The design landing stop, the maximum kinetic energy accelerate stop, and the most severe landing stop brake kinetic energy absorption requirements of each wheel and brake assembly must be determined. It must be substantiated by dynamometer testing that at the declared fully worn limit(s) of the brake heat sink, the wheel and brake assemblies are capable of absorbing not less than these levels of kinetic energy. Energy absorption rates defined by the aeroplane manufacturer must be achieved. These rates must be equivalent to mean decelerations not less than 10 ft/s^2 for the design landing stop and 6 ft/s^2 for the maximum kinetic energy accelerate-stop.
The design landing stop is an operational landing stop at maximum landing weight.
The maximum kinetic energy accelerate-stop is a rejected take-off at the most critical combination of aeroplane take-off weight and speed.
The most severe landing stop is a stop at the most critical combination of aeroplane landing weight and speed. The most severe landing stop need not be considered for extremely improbable failure conditions or if the maximum kinetic energy accelerate-stop energy is more severe.

(g) ***Brake Condition after High Kinetic Energy Dynamometer Stop(s).*** Following the high kinetic energy stop demonstration(s) required by sub-paragraph (f) of this paragraph, with the parking brake promptly and fully applied for at least three (3) minutes, it must be demonstrated that for at least five (5) minutes from application of the parking brake, no condition occurs (or has occurred during the stop), including fire associated with the tyre or wheel and brake assembly, that could prejudice the safe and complete evacuation of the aeroplane.

(h) ***Stored energy systems.*** An indication to the flight crew of usable stored energy must be provided if a stored energy system is used to show compliance with sub-paragraph (b)(1) of this paragraph. The available stored energy must be sufficient for:-

(1) At least six (6) full applications of the brakes when an anti-skid system is not operating, and

(2) Bringing the aeroplane to a complete stop when an anti-skid system is operating, under all runway surface conditions for which the aeroplane is certificated.

(i) ***Brake wear indicators.*** Means must be provided for each brake assembly to indicate when the heat sink is worn to the permissible limit. The means must be reliable and readily visible.

(j) ***Overtemperature burst prevention.*** Means must be provided in each braked wheel to prevent wheel failure and tyre burst that may result from elevated brake temperatures. Additionally, all wheels must meet the requirements of JAR 25.731(d).

(k) ***Compatibility.*** Compatibility of the wheel and brake assemblies with the aeroplane and its systems must be substantiated.

JAR-25 SECTION 2
ACJ - SUBPART D

Delete ACJ 25.735(a)

Delete ACJ 25.735(b)

Delete ACJ 25.735(c)

Delete ACJ 25.735(d)

Delete ACJ 25.735(e)

JAR-25 SECTION 3
ADVISORY MATERIAL JOINT - AMJ

Introduce a new Advisory Material (AMJ 25.735) as follows:-

AMJ 25.735
BRAKES AND BRAKING SYSTEMS - DESIGN, TEST, ANALYSIS AND CERTIFICATION

1. PURPOSE

This AMJ (Advisory Material Joint) which is similar to the FAA Advisory Circular AC 25.735-X, provides advice and guidance on the interpretation of the requirements and on the acceptable means, but not the only means, of demonstrating compliance with the requirements of JAR 25.731 and JAR 25.735. It also identifies other paragraphs of the Joint Aviation Requirements (JAR) that contain related requirements and other related and complementary documents.

2. RELATED REGULATORY MATERIAL AND COMPLEMENTARY DOCUMENTS

(a) Related Joint Aviation Requirements

JAR-21 and JAR-25 Paragraphs (and their associated ACJ/AMJ material where applicable) that prescribe requirements related to the design substantiation and certification of brakes and braking systems include:

JAR 21.303	Compliance with Requirements
JAR 25.101	General
JAR 25.109	Accelerate-stop distance
JAR 25.125	Landing
JAR 25.301	Loads
JAR 25.303	Factor of safety.
JAR 25.729	Retracting mechanism
JAR 25.733	Tyres
JAR 25.1301	Function and installation
JAR 25.1309	Equipment, systems and installations
JAR 25.1322	Warning, caution and advisory lights
JAR 25.1501	General: Systems and Equipment Limitations
JAR 25X1524	Systems and equipment limitations
JAR 25.1541	Markings and Placards: General
JAR 25X1591	Supplementary performance information

Additional JAR-21 and JAR-25 paragraphs (and their associated ACJ/AMJ material where applicable) that prescribe requirements which can have a significant impact on the overall design and configuration of brakes and braking systems are, but are not limited to:

JAR 21.101	Designation of applicable requirements
JAR 25.671	General: Control Systems
JAR 25.863	Flammable fluid fire protection
JAR 25.1001	Fuel jettisoning system
JAR 25.1183	Flammable fluid-carrying components
JAR 25.1185	Flammable fluids
JAR 25X1315	Negative acceleration (FAR 25.943)

(b) Complementary Documents

Documents that provide appropriate standards for the design substantiation and certification of Brakes and Braking Systems are, but are not limited to:

(i) . Joint Technical Standard Orders (JTSO)

JTSO-C47	Pressure Instruments - Fuel, Oil and Hydraulic
JTSO-C26c	Aircraft Wheels and Wheel-Brake Assemblies with Addendum I
JTSO-2C75	Hydraulic Hose Assemblies
JTSO-C62d	Aircraft Tyres
JTSO-C135	Transport Aeroplane Wheels and Wheel and Brake Assemblies

(ii) Advisory Circulars/Material

AC 25.1309-1A	System Design and Analysis
AC 25-7	Flight Test Guide for Certification of Transport Category Airplanes (Under Revision)
AC 21-29A	Detecting and Reporting Suspected Unapproved Parts
AC 91-6A	Water, Slush, and Snow on the Runway (AMJ 25X1591 Supplementary Performance Information for Takeoff from Wet Runways and for Operation on Runways Contaminated by Standing Water, Slush, Loose Snow, Compacted Snow, or Ice.)

(iii) Society of Automotive Engineers (SAE) Documents

ARP 597C	Wheels and Brakes, Supplementary Criteria for Design Endurance - Civil Transport Aircraft
ARP 813A	Maintainability Recommendations for Aircraft Wheels and Brakes
AIR 1064B	Brake Dynamics
ARP 1070B	Design and Testing of Antiskid Brake Control Systems for Total Aircraft Compatibility
AS 1145A	Aircraft Brake Temperature Monitor System (BTMS)
ARP 1619	Replacement and Modified Brakes and Wheels
AIR 1739	Information on Antiskid Systems
ARP 1907	Automatic Braking Systems Requirements
AIR 1934	Use of Carbon Heat Sink Brakes on Aircraft
ARP 4102/2	Automatic Braking System (ABS)
ARP 4752	Aerospace - Design and Installation of Commercial Transport Aircraft Hydraulic Systems (Note: This document provides a wide range of Civil, Military and Industry document references and standards which may be appropriate.)

(iv) International Organisation for Standardisation (ISO) Documents

ISO 7137	Environmental Conditions and Test Procedures for Airborne Equipment.

(v) US Military Documents

MIL-STD-810	Environmental Test Methods and Engineering Guidelines.

(vi) The European Organisation for Civil Aviation Equipment Documents

ED-14D/RTCA DO-160D	Environmental Conditions and Test Procedures for Airborne Equipment. Issued 29 July 1997
ED-12B/RTCA DO-178B	Software Considerations in Airborne Systems and Equipment Certification. Issued- 1 December 1992

3. ADVICE AND GUIDANCE

The advice and guidance provided does not in any way constitute additional requirements but reflects what is normally expected by the Joint Aviation Authorities (JAA).

(a) Ref. JAR 25.735(a) Approval

Each wheel and brake assembly, fitted with each designated and approved tyre type and size where appropriate, should be shown to be capable of meeting the minimum standards and capabilities detailed in the applicable Joint Technical Standard Order (J)TSO, in conjunction with the type certification procedure for the aeroplane, or by any other means approved by the Authority. This applies equally to replacement, modified, or refurbished wheel and brake assemblies or components whether the changes are made by the Original Equipment Manufacturer (OEM) or others.

Additionally, the components of the wheels, brakes and braking systems should be designed to:-

(i) Withstand all pressures and loads, applied separately and in conjunction, to which they may be subjected in all operating conditions for which the aeroplane is certificated.

(ii) Withstand simultaneous application of normal and emergency braking functions unless adequate design measures have been taken to prevent such a contingency.

(iii) Meet the energy absorption requirements without auxiliary cooling devices (such as cooling fans etc.).

(iv) Not induce unacceptable vibrations at any likely ground speed and condition or any operating condition (such as retraction or extension).

(v) Protect against the ingress or effects of such foreign bodies or materials (water, mud, oil and other products) which may adversely affect their satisfactory performance.

Combinations of any additional wheel and brake assemblies should meet applicable airworthiness requirements as specified in sub-paragraphs (a) and (b) of JAR 2 1 101 to eliminate situations that may have adverse consequences on aeroplane braking control and performance. This includes the possibility of the use of modified brakes either alone i.e., as a "ship set" or alongside original equipment manufacturer's brakes and the mixing of separately approved assemblies.

Refurbished and Overhauled Equipment. Refurbished and Overhauled Equipment is equipment overhauled and maintained in accordance with the OEM's Component Maintenance Manual (CMM) and associated documents. Refurbishment and overhaul of an approved brake by other than the applicable OEM or its designee is considered under Replacement and Modified Equipment. It is necessary to demonstrate compliance of all refurbished configurations with applicable (J)TSO and aeroplane manufacturer's specifications. It is also necessary to verify that performance is compatible for any combination of mixed brake configurations including refurbished/overhauled and new brakes. It is essential to assure that Aeroplane Flight Manual (AFM) braking performance and landing gear and aeroplane structural integrity are not adversely altered.

Replacement and Modified Equipment. Replacement and Modified Equipment include changes to any approved wheel and brake assembly. Consultation with the aeroplane manufacturer on the extent of testing is recommended. Particular attention should be paid to potential differences in the primary brake system parameters, e.g. brake torque, energy capacity, vibration, brake sensitivity, dynamic response, structural strength, wear state, etc.. If comparisons are made to previously approved equipment, the test articles (other than the proposed parts to be changed) and conditions should be comparable, as well as the test procedures and equipment on which comparative tests are to be conducted. For wheel and brake assembly tests; tyre size, manufacturer, and ply rating used for the test(s) should be the same, and the tyre conditions should be comparable. For changes of any heat sink component parts, structural parts (including the wheel), friction couples, etc., it is necessary for the applicant to provide evidence of acceptable performance and compatibility with the aeroplane and its systems.

Changes to a brake might be considered as a minor change, as long as the changes are not to the friction elements, and the proposed change(s) cannot affect the aeroplane stopping performances, brake energy absorption characteristics, and/or continued airworthiness of the aeroplane or wheel and brake assembly (e.g. vibration and/or thermal control. brake retraction integrity, etc.). It is incumbent on the applicant to provide technical evidence justifying whether a change is minor. Changes to a wheel assembly outside the limits allowed in the OEM's CMM should be considered a major change due to potential airworthiness issues.

Past history with friction elements has indicated the necessity of on-going monitoring (by dynamometer test) of frictional and energy absorption capability to assure that they are maintained over the life of the aeroplane programme. These monitoring plans have complemented the detection and correction of unacceptable deviations. The applicant should demonstrate that frictional energy absorption capabilities of the friction elements are maintained over time.

Intermixing of wheel and brake assemblies from different suppliers on the same aeroplane is generally not acceptable due to the complexities experienced with differing friction elements, specific brake control system tuning, and other factors.

(b) Ref. JAR 25.735(b) Brake System Capability

The system should be designed so that any *single* failure of the system does not affect aeroplane stopping performance beyond doubling the *braked* roll stopping distance. Failures are considered to be fracture, leakage, or jamming of a component in the system or loss of an energy source. Components of the system include all parts that contribute to transmitting the pilot's braking command to the actual generation of braking force. Multiple failures resulting from a single cause shall be considered a single failure, for example, fracture of two or more hydraulic lines as a result of a single failure. Sub-components within the brake assembly, such as brake discs, and actuators (or their equivalents), should be considered as connecting or transmitting elements, unless it is shown that leakage of hydraulic fluid resulting from failure of the sealing elements in these sub-components within the brake assembly would not reduce the braking effectiveness below that specified in JAR 25.735(b)(1).

In order to meet the stopping distance requirements of JAR 25.735(b)(1) in the event of a failure in the normal system, it is common practice to provide an alternate brake system. The normal and alternate (secondary/emergency) braking systems should be independent, being supplied by separate power sources. Following a failure in the normal system, the changeover to a second system (whether manually or by automatic means) and the functioning of a secondary power source, should be effected rapidly and safely and should not involve the risk of wheel locking whether the brakes are applied or not at the time of the changeover.

The brake system and components should be separated or appropriately shielded so that complete failure of the braking system(s) as a result of a single cause is minimised.

Compliance with JAR 25.735(b)(2) may be achieved by (i) showing that fluid released would not impinge on the brake, or any part of the assembly that might cause the fluid to ignite, (ii) showing that the fluid will not ignite, or (iii) showing that the maximum amount of fluid which is released is not sufficient to sustain a fire.

Additionally, in the case of a fire the applicant may show that the fire is not hazardous taking into consideration such factors as landing gear geometry, location of fire sensitive (susceptible) equipment and installations, system status, flight mode, etc.

(c) Ref. JAR 25.735(c) Brake Controls

The braking force should increase or decrease progressively as the force or movement applied to the brake control is increased or decreased and the braking force should respond to the control as quickly as is necessary for safe and satisfactory operation. A brake control intended only for parking need not operate progressively. There should be no requirement to select the parking brake off in order to achieve a higher braking force with manual braking.

When an automatic braking system is installed such that various levels of braking (e.g. low, medium, high etc.) may be preselected to occur automatically following a touchdown, the pilot(s) should be provided with a means to arm and/or disarm the system prior to the touchdown that is separate from other brake controls.

The automatic braking system design should be evaluated for integrity and non-hazard, including the probability and consequence of insidious failure of critical components, and non-interference with the manual braking system. Single failures in the automatic braking system should not compromise non-automatic braking of the aeroplane. Automatic braking systems that are to be approved for use in the event of a rejected take-off should have a single selector position, set prior to take-off enabling this operating mode.

(d) Ref. JAR 25.735(d) Parking Brake

It should be demonstrated that the parking brake has sufficient capability in all allowable operating conditions (including Master Minimum Equipment List (MMEL) conditions) to be able to prevent the rotation of braked wheels (as opposed to skidding), with the stated engine power settings, and with the aeroplane configuration, (i.e. ground weight C of G position, and nose-wheel (or tail-wheel) angle), least likely to result in skidding on a dry and level runway surface. Where reliable test data are available, substantiation by means other than aeroplane testing may be acceptable.

For compliance with the requirement for indication that the parking brake is not: fully released, the indication means should be as closely associated with brake actuation as is practicable, rather than the selector (control). This requirement is separate from and in addition to the parking brake requirements associated with JAR 25.703(a)(3) Take-off warning systems.

The parking brake control, whether or not it is independent of the emergency brake control, should be marked with the words "Parking Brake" and should be constructed in such a way that, once operated, it can remain in the selected position without further flight crew attention. It should be located where inadvertent operation is unlikely or be protected, by suitable means, against inadvertent operation.

(e) Ref. JAR 25.735 (e) Antiskid System

No single failure in the anti-skid system should result in the brakes being applied unless braking is being commanded by the pilot. In the event of any failure, an automatic or pilot controlled means (or both) should be available to allow continued braking without anti-skid.

Failures which render the system ineffective should not prevent manual braking control by the pilot(s) and should normally be indicated. Failure of brakes, wheels or tyres should not inhibit the function of the antiskid system for unaffected wheel brake and tyre assemblies.

The anti-skid system should be capable of giving satisfactory braking performance over the full range of tyre to runway friction coefficients and surface conditions without the need for pre-flight or pre-landing adjustments or selections. The range of fiction coefficients should encompass those appropriate to dry, wet and contaminated surfaces and for both grooved and ungrooved runways.

The use of the phrase "...without external adjustment" of (e)(1) is intended to imply that once the antiskid system has been optimised for operation over the full range of expected conditions for which the aeroplane is to be type certificated, pre-flight or pre-landing adjustments made to the equipment to enable the expected capabilities to be achieved, are not acceptable. For example, a specific pre-landing selection for a landing on a contaminated, low μ runway following a take off from a dry, high μ surface should not be necessary for satisfactory braking performance to be achieved.

It should be shown that the brake cycling frequency imposed by the antiskid installation will not result in excessive loads on the landing gear. Antiskid installations should not cause surge pressures in the brake hydraulic system which would be detrimental to either the normal or emergency brake system and components.

The system should be compatible with all tyre size and type combinations permitted and for all allowable wear states of the brakes and tyres. Where brakes of different types or manufacture are permitted, compatibility should be demonstrated or appropriate means should be employed to ensure that undesirable combinations are precluded.

(f) Ref. JAR 25.735(f) Kinetic Energy Capacity

The kinetic energy capacity of each tyre, wheel, and brake assembly should be at least equal to that part of the total aeroplane energy that the assembly will absorb during a stop, with the heat sink at a defined condition at the commencement of the stop.

(1) Calculation of Stop Kinetic Energy

The design landing stop, the maximum kinetic energy accelerate-stop, and the most severe landing stop brake kinetic energy absorption requirements of each wheel and brake assembly should be determined using either of the following methods:

(i) A conservative rational analysis of the sequence of events expected during the braking manoeuvre, or

(ii) A direct calculation based on the aeroplane kinetic energy at the commencement of the braking manoeuvre.

When determining the tyre, wheel and brake assembly kinetic energy absorption requirement using the rational analysis method, the analysis should use conservative values of the aeroplane speeds at which the brakes are first applied, the range of the expected coefficient of friction between the tyres and runway, aerodynamic and propeller drag, powerplant forward thrust, and, if more critical, the most adverse single engine or propeller malfunction.

When determining the tyre, wheel and brake assembly energy absorption requirements using the direct calculation method, the following formula, which needs to be modified in cases of designed unequal braking distribution, should be used:

$KE = 0.0443\ WV^2/N$ (ft lb)

Where,	KE	=	Kinetic energy per wheel (ft lb)
	N	=	Number of wheels with brakes
	w	=	Aeroplane weight (lb)
	V	=	Aeroplane speed (Knots)

OR

$KE = 0.5m\ V^2/N$ (Joule)

Where,	KE	=	Kinetic energy per wheel (J)
	N	=	Number of wheels with brakes
	m	=	Aeroplane mass (Kg)
	v	=	Aeroplane speed (m/s)

For all cases, V is the ground speed and takes into account the prevailing operational conditions. All approved landing flap conditions should be considered when determining the design landing stop energy.

These calculations should take into account cases of designed unequal braking distributions. "Designed unequal braking distributions" refers to unequal braking loads between wheels that result directly from the design of the aeroplane: for example due to the use of both main-wheel and nose-wheel brakes, or the use of brakes on a centre-line landing gear supporting lower vertical loads per braked wheel than the main landing gear braked wheels. It is intended that this term should take account of effects such as runway crown. Crosswind effects need not be considered.

For the design landing case, the aeroplane speed must not be less than $V_{REF}/1.3$ where V_{REF} is the aeroplane steady landing approach speed at the maximum design landing weight and in the landing configuration at sea level. Alternatively, the aeroplane speed must not be less than V_{SO} the power-off stall speed of the aeroplane at sea level at the design landing weight, and in the landing configuration.

(2) Heat sink condition at the commencement of the stop

For the maximum kinetic energy accelerate-stop case the calculation should take account of the brake temperature following a previous typical landing, the effects of braking during taxi-in, the temperature change whilst parked, the effects of braking during taxi-out, and the temperature change during the take-off acceleration phase up to the time of brake application. The analysis may not take account of auxiliary cooling devices. Conservative assessments of typical ambient conditions and the time the aeroplane will be on the ground, should be used.

For the most severe landing stop case, the same temperature conditions and changes used for the maximum kinetic energy accelerate-stop case should be assumed, except that further temperature change during the additional flight phase may be considered The duration of this additional flight phase should be determined as the minimum practicable between the take-off and landing on the same runway with the aeroplane in a configuration which would enable such a return to be made. However, should it be determined that the most severe landing stop can only reasonably occur after a more extended flight phase, this may also influence the determined heat sink temperature.

The brake temperature at the commencement of the braking manoeuvre should be determined using the rational analysis method except that, in the absence of such analysis, an arbitrary heatsink temperature equal to the normal ambient temperature increased by the amount that would result from a 10% maximum kinetic energy accelerate-stop for the accelerate-stop case and from a 5% maximum kinetic energy accelerate-stop for landing cases should be used.

(3) Substantiation

Substantiation that the wheel and brake assemblies are capable of absorbing the determined levels of kinetic energy at all permitted wear states, up to and including the declared fully worn limits, is required. The term wear "state" is used in order to clarify that consideration should be given to possible inconsistencies or irregularities in brake wear in some circumstances, such as greater wear at one end of the heat sink than the other. Qualification related to evenly distributed heat sink wear may not be considered adequate. If the typical in-service wear distribution is significantly different from the wear distribution used during qualification testing, additional substantiation and/or corrective action may be necessary.

The minimum initial brakes-on speed used in the dynamometer test should not be more than the velocity (V) used in the determination of JAR 25.735(f) kinetic energy requirements. This assumes that the test procedure involves a specified rate of deceleration and therefore, for the same amount of kinetic energy, a higher initial brakes-on speed would result in a lower rate of energy absorption. However, a brake test having a higher initial brakes-on speed is acceptable if the dynamometer test showed that both the energy absorbed and energy absorption rate required by JAR 25.735(f) had been achieved. Such a situation is recognised and is similarly stated in the (J)TSO-C135, which provides an acceptable means for brake approval under JAR 25.735(a).

Brake qualification tests are not intended as a means of determining expected aeroplane stopping performance, but may be used as an indicator for the most critical brake wear state for aeroplane braking performance measurements.

(g) Ref. JAR 25.735(g) Brake Condition after High Kinetic Energy Dynamometer Stop(s)

Following the high kinetic energy stop(s), the parking brake should be capable of restraining further movement of the aeroplane and should maintain this capability for the period during which the need for an evacuation of the aeroplane can be determined and then fully accomplished.

It should be demonstrated that, with a parking brake application within a period not exceeding 20 seconds of achieving a full stop, or within 20 seconds from the time that the speed is retarded to 20 knots (or lower) in the event that the brakes are released prior to achieving a full stop (as permitted by (J)TSO-C135), the parking brake can be applied normally and that it remains functional over the three (3) minutes required.

Practical difficulties associated with dynamometer design may preclude directly demonstrating the effectiveness of the parking brake in the period immediately following the maximum energy dynamometer stop(s). Where such difficulties prevail it should be shown that, for the three (3) minute period no structural failure or other condition of the brake components occur that would significantly impair the parking brake function.

Regarding the initiation of a fire, it should be demonstrated that no continuous or sustained fire extending above the highest point of the tyre occurs before the five (5) minute period has elapsed. Neither should any other condition arise during this same period or during the stop, either separately or in conjunction with a fire, which could be reasonably judged to prejudice the safe and complete aeroplane evacuation. Fire of limited extent and of a temporary nature (e.g. involving wheel bearing lubricant or minor oil spillage) is acceptable. For this demonstration, neither fire fighting means nor coolants may be applied.

(h) Ref. JAR 25.735(h) Stored energy systems

Stored energy systems use a self-contained source of power such as a gas pressurised hydraulic accumulator or a charged battery.

This requirement is not applicable to those aeroplanes that provide a number of independent braking systems, even though they may incorporate a stored energy source(s), but which are not "reliant" on the stored energy system for the demonstration of compliance with sub-paragraph (b) of this paragraph.

The indication of usable stored energy should show:

(1) The minimum energy level necessary to meet the requirements of JAR 25.735 (b)(1) and (h), i.e. the acceptable level for dispatch of the aeroplane,

(2) The remaining energy level, and,

(3) The energy level below which further brake application may not be possible.

If a gas pressurised hydraulic accumulator is to be used as the energy storage means, indication of accumulator pressure alone is not considered adequate means to indicate available stored energy.

An accumulator pressure gauge may be acceptable if correct precharge pressure with the hydraulic system pressure off and the correct fluid volume with the hydraulic system pressure on, can be verified. Furthermore, additional safeguards may be necessary to ensure that sufficient stored energy will be available at the end of the flight.

Similar considerations should be made when other energy storage means are used

A full brake application is defined as application from brakes fully released to brakes fully applied and back to fully released.

(i) Ref. JAR 25.735(i) Brake wear indicators

The indication means should be located such that no special tool or illumination (except in darkness) is required. Expert interpretation of the indication should not be necessary.

(j) Ref. JAR 25.731(d) and JAR 25.735(j) Overtemperature and Overpressure Burst Prevention

Generally, two separate types of protection should be provided; one specifically to release the tyre pressure should the wheel temperature increase to an unacceptable level, and the other to release the tyre pressure should the pressure become unacceptably high, particularly during the inflation process. The temperature sensitive devices are required in braked wheels only, but the pressure sensitive devices are required in all wheels.

The temperature sensitive device(s), (e.g. a fuse or fusible plug), should be sufficient in number and appropriately located to reduce the tyre pressure to a safe level, before any part of the wheel becomes unacceptably hot, irrespective of the wheel orientation. The device(s) should be designed and installed such that once operated (or triggered), their continued operation is not impaired by the releasing gas.

The effectiveness of these devices in preventing hazardous tyre blow-out or whee failure should-be demonstrated. It should also be demonstrated that the devices will not release the tyre pressure prematurely during take-off or landing, including during "quick turn-around" types of operation.

It should be shown that the overpressurisation protection device(s), or the device(s) in combination *with the* inflation means *permanently* installed in the wheel, would not permit the tyre pressure to reach an unsafe level, regardless of the capability of the inflation source.

Both types of device should normally be. located within the structure of the wheel in positions which minimise the risk of damage or tampering during normal maintenance.

(k) Ref. JAR 25.735(k) Compatibility

During brake qualification testing, sufficient dynamometer testing over the range of permissible brake wear states, energy levels, brake pressures, brake temperatures and speeds should be undertaken to provide information necessary for systems integration. As part of the overall substantiation of safe and anomaly free operation, it is necessary to show that no unsafe conditions arise from incompatibilities between the brakes and brake system with other aeroplane systems and structures. Areas such as antiskid tuning, landing gear dynamics, tyre type and size, brake combinations, brake characteristics, brake and landing gear vibrations, etc. need to be explored. Similarly, wheel and tyre compatibility should be addressed.

These issues should be re-addressed when the equipment is modified.

JOINT AVIATION AUTHORITIES

NOTICE OF PROPOSED AMENDMENT (NPA) COMMENT FORM
(See reverse side for guidelines)

1. **NPA NUMBER: NPA TSO-7**

Requirement paragraph.. .
ACJ/AMJ or AMC/IEM paragraph......

2. **POSITION (see 3.. on** the reverse side)

Agree / Accept / No comment.
Propose different text / general comment (see 3. below).
Propose to delete paragraph (see reverse side for explanation).

3. **PROPOSED TEXT/COMMENT**

Reason(s) for proposed text/comment

4. **ORGANISATION..**
Address ....

Telephone.. ....
Telefax..............

5. **SIGNATURE.. .....**

Date:

Name.. ....

JAA Form 200

September 1995

Guidelines for the use of the NPA Comment Form

1. This form should be seen as guidance material for cornmentors. Its, or any similar form's, use is not mandatory, but is useful for the expeditious examination of comments.

2. If there is insufficient space on the form, use the blank space on this side or attachments.

3. Cross out the parts of 2. that are not applicable.

   In case of disagreement, cornmentors should be aware that failure to propose a text and explain the reason(s) for this text may well result in the comments being laid aside for lack of understanding. For the same reason, the commentor should explain a proposal to delete a paragraph.

4. Cornmentors may copy this form or procure extra copies from JAA Headquarters.

5. All comments should be sent to the JAA Regulation Director at JAA Headquarters unless otherwise indicated in the NPA.

Subject : JTSO-C135, Transport Aeroplane Wheels and Wheel and Brake Assemblies.

1 - Applicability.

This Joint Technical Standard Order ((J)TSO) prescribes the minimum performance standard that transport category aeroplane wheels, and wheel and brake assemblies must meet to be identified with the applicable (J)TSO marking. Articles that are to be so identified on or after the date of this (J)TSO, must meet the requirements of Appendix 1 of this (J)TSO titled, "Minimum Performance Specification for Transport Aeroplane Wheels, Brakes, and Wheel and Brake Assemblies," dated [ ]. Brakes and associated wheels are to be considered as an assembly for (J)TSO authorisation purposes.

2 - Marking.

2.1 In addition to the marking specified in JAR-21 Sub-part 0 paragraph 21.607, the following information shall be legibly and permanently marked on the major equipment components:

(i) Size (this marking applies to wheels only).
(ii) Hydraulic fluid type (this marking applies to hydraulic brakes only).
(iii) Serial Number.

2.2 All stamped, etched, or embossed markings must be located in non-critical areas.

3 - Data Requirements.

In addition to the data specified in paragraph 21.605 of JAR-21 Sub-part O, the manufacturer must furnish one copy each of the following to their National Airworthiness Authority:

3.1 The applicable limitations pertaining to installation of wheels or wheel and brake assemblies on aeroplane(s), including the data requirements of paragraph 4.1 of Appendix 1 of this (J)TSO.

3.2 The manufacturer's (J)TSO qualification test report.

4 - Data to be Furnished with Manufactured Articles.

4.1 Prior to entry into service use, the manufacturer must make available to their National Airworthiness Authority all applicable maintenance instructions and data necessary for continued airworthiness.

4.2 The manufacturer must provide the applicable maintenance instructions and data necessary for continued airworthiness to each organisation or person receiving one or more articles manufactured under this (J)TSO. In addition, a note with the following statement must be included:

"The existence of (J)TSO approval of the article displaying the required marking does not automatically constitute the authority to install and use the article on an aeroplane. The conditions and tests required for (J)TSO approval of this article are minimum performance standards. It is the responsibility of those desiring to install this article either on or within a specific type or class of aeroplane to determine that the aeroplane operating conditions are within the (J)TSO standards. The article may be installed only if further evaluation by the user/installer documents an acceptable installation and the installation is approved by the Authority.

Additional requirements may be imposed based on aeroplane specifications, wheel and brake design, and quality control specifications. In-service maintenance. modifications, and use of replacement components must be in compliance with the performance standards of this (J)TSO, as well as any additional specific aeroplane requirements."

5 - Previously Approved Equipment.

Wheels and wheel-brake assemblies approved prior to the effective date of this (J)TSO may continue to be manufactured under the provisions of their original approval.

6 - Reference Documents and Availability.

6.1 JAR-21 may be obtained from (((Address etc. to be inserted))).

6.2 JAR-TSO and this (J)TSO may be obtained from (((Address etc. to be inserted))).

APPENDIX 1 : MINIMUM PERFORMANCE SPECIFICATION FOR TRANSPORT AEROPLANE WHEELS, BRAKES, AND WHEEL AND BRAKE ASSEMBLIES,

CHAPTER 1
INTRODUCTION.

1.1 PURPOSE AND SCOPE.

This Minimum Performance Specification defines the minimum performance standards for wheels, brakes, and wheel and brake assemblies to be used on aeroplanes certified to JAR-25. Compliance with this specification is not considered approval for installation on any transport aeroplane.

1.2 APPLICATION.

Compliance with this minimum specification by manufacturers, installers and users is required as a means of assuring that the equipment will have the capability to satisfactorily perform its intended function(s).

Note: Certain performance capabilities may be affected by aeroplane operational characteristics and other external influences. Consequently, anticipated aeroplane braking performance should be verified by aeroplane testing.

1.3 COMPOSITION OF EQUIPMENT.

The words "equipment" or "brake assembly" or "wheel assembly," as used in this document, include all components that form part of the particular unit.

For example, a wheel assembly typically includes a hub or hubs, beatings, flanges, drive bars, heat shields, and fuse plugs. A brake assembly typically includes a backing plate. torque tube, cylinder assemblies, pressure plate, heat sink, and temperature sensor.

It should not be inferred from these examples that each wheel assembly and brake assembly will necessarily include either all or any of the above example components; the actual assembly will depend on the specific design chosen by the manufacturer.

1.4 DEFINITIONS AND ABBREVIATIONS.

1.4.1 Wheel Rated Static Load (S)

S = Maximum Static Load (Reference JAR 25.731(b)).

1.4.2 Wheel Rated Inflation Pressure (WRP).

WRP = Wheel Rated Inflation Pressure (wheel unloaded).

1.4.3 Wheel Rated Tyre Loaded Radius (R).

R = Static Radius at load "S" for the Wheel Rated Tyre Size at WRP. The static radius is defined as the minimum distance from the axle centreline to the tyre/ground contact interface.

1.4.4 Wheel Rated Radial Limit Load IL).

L = Radial Limit Load. L is the Wheel Rated Maximum Radial Limit Load (paragraph 3.2.1).

1.4.5 Wheel Rated Tyre Type and Size (TS_{WR}).

TS_{WR} = Wheel Rated Tyre Type and Size approved for installation on the wheel.

1.4.6 Suitable Tyre for Wheel Test (TS_{WT}).

TT_{WT} = Wheel Rated Tyre Type and Size for Wheel Test.

TT_{WT} is the tyre type and size determined as being the most appropriate to introduce loads and/or pressure that would induce the most severe stresses in the wheel. TT_{WT} must be a tyre type and size approved for installation on the wheel (TS_{WR}) The suitable tyre may be different for different tests.

1.4.7 Wheel/Brake Rated Structural Torque (ST_R).

ST_R = Wheel/Brake Rated Structural Torque.

ST_R is the maximum structural torque demonstrated (paragraph 3.3.5).

1.4.8 Wheel/Brake Rated Design Landing Stop Energy (KE_{DL}).

KE_{DL} = Wheel/Brake Rated Design Landing Stop Energy.

KE_{DL} is the minimum energy absorbed by the wheel/brake/tyre assembly during each stop of the 100 stop Design Landing Stop Test. (paragraph 3.3.2).

1.4.9 Wheel/Brake Design Landing Stop Speed (V_{DL}).

V_{DL} = Wheel/Brake Design Landing Stop Speed.

V_{DL} is the initial brakes-on speed for a Design Landing Stop (paragraph 3.3.2)

1.4.10 Wheel/Brake Rated Accelerate-Stop Energy (KE_{RT}).

KE_{RT} = Wheel/Brake Rated Accelerate-Stop Energy.

KE_{RT} is the energy absorbed by the wheel/brake/tyre assembly demonstrated in accordance with the Accelerate-Stop test in paragraph 3.3.3.

1.4.11 Wheel/Brake Accelerate-Stop Speed (V_{RT}).

V_{RT} = Wheel/Brake Accelerate-Stop Speed.

V_{RT} is the initial brakes-on speed used to demonstrate KE_{RT} (paragraph 3.3.3)

1.4.12 Wheel/Brake Rated Most Severe Landing Stop Energy (KE_{SS}).

KE_{SS} = Wheel/Brake Rated Most Severe Landing Stop Energy.

KE_{SS} is the energy absorbed by the wheel/brake/tyre assembly demonstrated in accordance with paragraph 3.3.4.

1.4.13 Wheel/Brake Most Severe Landing Stop Speed (V_{SS}).

V_{SS} = Wheel/Brake Most Severe Landing Stop Speed.

V_{SS} is the initial brakes-on speed used to demonstrate KE_{SS} (paragraph 3.3.4).

1.4.14 Brake Rated Wear Limit (BRWL).

BRWL = Brake maximum wear limit to ensure compliance with paragraph 3.3.3, and, if applicable, paragraph 3.3.4.

1.4.15 Aeroplane Maximum Rotation Speed (V_R).

V_R = Aeroplane Maximum Rotation Speed.

1.4.16 Brake Rated Maximum Operating Pressure ($BROP_{MAX}$).

$BROP_{MAX}$ = Brake Rated Maximum Operating Pressure.

$BROP_{MAX}$ is the maximum design metered pressure which is available to the brake to meet aeroplane stopping performance requirements.

1.4.17 Brake Rated Maximum Pressure (BRP_{MAX}).

BRP_{MAX} = Brake Rated Maximum Pressure

BRP_{MAX} is the maximum pressure to which the brake is designed to be subjected (typically aeroplane nominal maximum system pressure).

1.4.18 Brake Rated Maximum Parking Pressure ($BRPP_{MAX}$).

$BRPP_{MAX}$ = Brake Rated Maximum Parking Pressure.

$BRPP_{MAX}$ is the maximum parking pressure available to the brake.

1.4.19 Brake Rated Retraction Pressure (BRP_{RET}).

BRP_{RET} is the highest pressure at which piston retraction to the unpressurised position is assured.

1.4.20 Distance Averaged Deceleration (D).

D = ((Initial brakes-on speed)^2 - (Final brakes-on speed)^2)/(2 (braked flywheel distance))

D is the distance averaged deceleration to be used in all deceleration calculations

1.4.21 Rated Design Landing Deceleration (D_{DL}).

D_{DL} = Rated Design Landing Deceleration.

D_{DL} is the minimum of the distance averaged deceleration values demonstrated during the 100 KE_{DL} stops of paragraph 3.3.2.

1.4.22 Rated Accelerate-Stop Deceleration (D_{RT}).

D_{RT} = Rated Accelerate-Stop Deceleration.

D_{RT} is the distance averaged deceleration which the wheel/brake/tyre assembly will produce when absorbing KE_{RT}.

1.4.23 Rated Most Severe Landing Stop Deceleration (D_{SS}).

D_{SS} = Rated Most Severe Landing Stop Deceleration.

D_{SS} is the distance averaged deceleration which the wheel/brake/tyre assembly will produce when absorbing KE_{SS}.

1.4.24 Brake Rated Tyre Type and Size (TS_{BR}).

TS_{BR} = Brake Rated Tyre Type and Size.

TS_{BR} is the tyre type and size used to achieve the KE_{DL}, KE_{RT}, and KE_{SS} brake ratings.

1.4.25 Suitable Tyre for Brake Tests (TT_{BT}).

TT_{BT} = Rated Tyre Type and Size.

TT_{BT} is the tyre type and size that has been determined as being the most critical for brake performance and/or energy absorption tests. TT_{BT} must be a tyre type and size approved for installation on the wheel (TS_{WR}). The suitable tyre may be different for different tests.

1.4.26 Brake Lining.

Brake lining is individual blocks of wearable material, discs that have wearable material integrally bonded to them, or discs in which the wearable material is an integral part of the disc structure.

1.4.27 Heat Sink.

The heat sink is the mass of the brake that is primarily responsible for absorbing energy during a stop. For a typical brake. this would consist of the stationary and rotating disc assemblies.

CHAPTER 2
GENERAL DESIGN SPECIFICATION.

2.1 AIRWORTHINESS.

The airworthiness of the aeroplane on which the equipment is to be installed must be considered. (See the paragraph titled "Data to be Furnished with Manufactured Articles.")

2.2 FIRE PROTECTION.

Except for small parts (such as fasteners, seals, grommets and small electrical parts) that would not contribute significantly to the propagation of a fire, all solid materials used must be self-extinguishing. See also paragraphs 3.3.3.5 and 3.3.4.5.

2.3 DESIGN.

Unless shown to be unnecessary by test or analysis, the equipment must comply with the following:

2.3.1 Wheel Bearing Lubricant Retainers.

Wheel bearing lubricant retainers must retain the lubricant under all operating conditions, prevent the lubricant from reaching braking surfaces, and prevent foreign matter from entering the bearings.

2.3.2 Removable Flanges.

All removable flanges must be assembled onto the wheel in a manner that will prevent the removable flanges and retaining devices from leaving the wheel if a tyre deflates while the wheel is rolling.

2.3.3 Adjustment.

The brake mechanism must be equipped with suitable adjustment devices to maintain appropriate running clearance when subjected to BRP_{RET}.

2.3.4 Water Seal.

Wheels intended for use on amphibious aircraft must be sealed to prevent entrance of water into the wheel bearings or other portions of the wheel or brake, unless the design is such that brake action and service life will not be impaired by the presence of sea water or fresh water.

2.3.5 Burst Prevention.

Means must be provided to prevent wheel failure and tyre burst that might otherwise result from overpressurisation or from elevated brake temperatures. The means must take into account the pressure and the temperature gradients over the full operating range.

2.3.6 Wheel Rim and Inflation Valve.

The rim dimensions and inflation valve should be approved by The European Tyre and Rim Technical Organisation (Reference: Aircraft Tyre and Rim Data Book). or, alternatively, The Tyre and Rim Association (Reference: Aircraft Year Book-Tyre and Rim Association Inc.)

2.3.7 Brake Piston Retention.

The brake must incorporate means to ensure that the actuation system does not allow hydraulic fluid to escape if the limits of piston travel are reached.

2.3.8 Wear Indicator.

A reliable method must be provided for determining when the heat sink is worn to its permissible limit

2.3.9 Wheel Bearings.

Means should be incorporated to avoid misassembly of wheel bearings.

2.3.10 Fatigue.

The design of the wheel must incorporate techniques to improve fatigue resistance of critical areas of the wheel and minimise the effects of the expected corrosion and temperature environment. The wheel must include design provisions to minimise the probability of fatigue failures that could lead to flange separation or other wheel burst failures.

2.3.11 Dissimilar Metals.

Adequate protection must be provided to prevent electrolytic action when dissimilar metals are used. In addition, differential thermal expansion must not unduly affect the load capability and fatigue life.

2.4 CONSTRUCTION.

2.4.1 Castings.

Castings must be of high quality, clean sound, and free from blowholes, porosity, or surface defects caused by inclusions, except that loose sand or entrapped gases may be allowed when serviceability is not impaired.

2.4.2 Forgings.

Forgings must be of uniform condition, free from blisters, fins, folds, seams, laps, cracks, segregation, and other defects. Imperfections may be removed if strength and serviceability would not be impaired as a result..

2.4.3 Bolts and Studs.

When bolts or studs are used for fastening together sections of a wheel or brake, the length of the threads must be sufficient to fully engage the nut, including its locking feature, and there must be sufficient unthreaded bearing area to carry the required load.

2.4.4 Corrosion Protection.

Corrosion protection means, where used, must be compatible with the expected environment. This protection must include protection for all holes and passages exposed to potentially corrosive environments.

2.4.5 Magnesium Parts.

Magnesium parts must not be used on brakes or braked wheels.

2.4.6 Bearing and Braking Surface.

Surface and protective finishes must not be applied to bearings and braking surfaces.

CHAPTER 3
MINIMUM PERFORMANCE UNDER STANDARD TEST CONDITIONS.

3.1 INTRODUCTION.

The test conditions and performance criteria described in this Chapter provide a laboratory means of demonstrating compliance with this (J)TSO minimum performance standard. The aeroplane manufacturer must define all relevant test parameter values.

3.2 WHEEL TESTS.

To establish the ratings for a wheel, it must be substantiated that standard production wheel samples will meet the following radial load, combined load, roll load, roll-on-rim (if applicable) and overpressure test requirements.

For all tests, except the roll-on-rim test of paragraph 3.2.4, the wheel must be fitted with a suitable tyre, TT_{WT}, and wheel loads must be applied through the tyre. The ultimate load tests of paragraphs 3.2.1.3 and 3.2.2.3 provide for an alternative method of loading if it is not possible to conduct these tests with the tyre mounted.

3.2.1 Radial Load Test.

If the radial limit load of paragraph 3.2.2 is equal to or greater than the radial limit load of this paragraph, the test specified in this paragraph may be omitted.

Test the wheel for yield and ultimate loads as follows:

3.2.1.1 Test method.

With a suitable tyre, TT_{WT}, installed, mount the wheel on its axle, and position it against a flat, non-deflecting surface. The wheel axle must have the same angular orientation to the non-deflecting surface that it will have to a flat runway when it is mounted on an aeroplane and is under the maximum radial limit load, L. Inflate the tyre to the pressure recommended for the Wheel Rated Static Load, S, with gas and/or liquid.

If liquid inflation is used, liquid must be bled off to obtain the same tyre deflection that would result if gas inflation were used.

Liquid pressure must not exceed the pressure that would develop if gas inflation were used and the tyre were deflected to its maximum extent. Load the wheel through its axle with the load applied perpendicular to the flat, non-deflecting surface. Deflection readings must be taken at suitable points to indicate deflection and permanent set of the wheel rim at the bead seat.

3.2.1.2 Yield Load.

Apply to the wheel and tyre assembly a load not less than 1.15 times the maximum radial limit load, L, as determined under JAR 25.471 to JAR 25.511 inclusive, as appropriate.

Determine the most critical wheel orientation with respect to the non-deflecting surface. Apply the load with the tyre loaded against the non-deflecting surface, and with the wheel rotated 90 degrees with respect to the most critical orientation . Repeat the loading with the wheel 180, 270, and 0 degrees from the most critical orientation. The bearing cups, cones, and rollers used in operation must be used for these loadings.

Three successive loadings at the 0 degree position must not cause permanent set increments of increasing magnitude. The permanent set increment caused by the last loading at the 0 degree position may not exceed 5% of the deflection caused by that loading or .005 inches (.125 mm), whichever is greater. There must be no yielding of the wheel such as would result in loose bearing cups, liquid or gas leakage through the wheel or past the wheel seal. There must be no interference in any critical areas between the wheel and brake assembly, or between the most critical deflected tyre and brake (with fittings) up to limit load conditions, taking into account the axle flexibility. Lack of interference can be established by analyses and/or tests.

3.2.1.3 Ultimate Load.

Apply to the wheel used in the yield test of paragraph 3.2.1.2, and the tyre assembly, a load not less than 2 times the maximum radial limit load, L, for castings, and 1.5 times the maximum radial limit load, L, for forgings, as determined under JAR 25.471 to JAR 25.511 inclusive, as appropriate.

Apply the load with the tyre and wheel against the non-deflecting surface and the wheel positioned at 0 degree orientation (paragraph 3.2.1.2). The bearing cones may be replaced with conical bushings, but the cups used in operation must be used for this loading. If, at a point of loading during the test, it is shown that the tyre will not successfully maintain pressure or if bottoming of the tyre occurs, the tyre pressure may be increased. If bottoming of the tyre continues to occur with increased pressure, a loading block that fits between the rim flanges and simulates the load transfer of the inflated tyre may be used. The arc of the wheel supported by the loading block must be no greater than 60 degrees.

The wheel must support the load without failure for at least 3 seconds. Abrupt loss of load-carrying capability or fragmentation during the test constitutes failure.

3.2.2 Combined Radial and Side Load Test.

Test the wheel for the yield and ultimate loads as follows:

3.2.2.1 Test Method.

With a suitable tyre, TT_{WT}, installed, mount the wheel on its axle and position it against a flat, non-deflecting surface. The wheel axle must have the same angular orientation to the non-deflecting surface that it will have to a flat runway when it is mounted on an aeroplane and is under the combined radial and side limit loads. Inflate the tyre to the pressure recommended for the maximum static load with gas and/or liquid.

If liquid inflation is used, liquid must be bled off to obtain the same tyre deflection that would result if gas inflation were used.

Liquid pressure must not exceed the pressure that would develop if gas inflation were used and the tyre were deflected to its maximum extent. For the radial load component, load the wheel through its axle with load applied perpendicular to the flat non-deflecting surface. Apply the two loads simultaneously, increasing them either continuously or in increments no greater than 10% of the total loads to be applied.

If it is impossible to generate the side load because of friction limitations, the radial load may be increased, or a portion of the side load may be applied directly to the tyre/wheel. In such circumstances it must be demonstrated that the moment resulting from the side load is no less severe than would otherwise have occurred.

Alternatively, the vector resultant of the radial and side loads may be applied to the axle. Deflection readings must be taken at suitable points to indicate deflection and permanent set of the wheel rim at the bead seat.

3.2.2.2 Combined Yield Load.

Apply to the wheel and tyre assembly radial and side loads not less than 1.15 times the respective ground limit loads, as determined under JAR 25.485, 25.495, 25.497, and 25.499, as appropriate.

Determine the most critical wheel orientation with respect to the non-deflected surface

Apply the load with the tyre loaded against the non-deflecting surface, and with the wheel rotated 90 degrees with respect to the most critical orientation. Repeat the loading with the wheel 180, 270, and 0 degrees from the most critical orientation.

The bearing cups, cones, and rollers used in operation must be used in this test.

A tube may be used in a tubeless tyre only when it has been demonstrated that pressure will be lost due to the inability of a tyre bead to remain properly positioned under the load. The wheel must be tested for the most critical inboard and outboard side loads.

Three successive loadings at the 0 degree position must not cause permanent set increments of increasing magnitude. The permanent set increment caused by the last loadings at the 0 degree position must not exceed 5% of the deflection caused by the loading, or .005 inches (.125 mm), whichever is greater. There must be no yielding of the wheel such as would result in loose bearing cups, gas or liquid leakage through the wheel or past the wheel seal. There must be no interference in any critical areas between the wheel and brake assembly, or between the most critical deflected tyre and brake (with fittings) up to limit load conditions, taking into account the axle flexibility. Lack of interference can be established by analyses and/or tests.

3.2.2.3 Combined Ultimate Load.

Apply to the wheel, used in the yield test of paragraph 3.2.2.2, radial and side loads not less than 2 times for castings and 1.5 times for forgings, the respective ground limit loads as determined under JAR 25.485, 25.495, 25.497, and 25.499, as appropriate.

Apply these loads with a tyre and wheel against the non-deflecting surface and the wheel positioned at the 0 degree orientation (paragraph 3.2.2.2). The bearing cones may be replaced with conical bushings; however, the cups used in operation must be used for this loading.

If, at any point of loading during the test, it is shown that the tyre will not successfully maintain pressure, or if bottoming of the tyre on the non-deflecting surface occurs, the tyre pressure may be increased. If bottoming of the tyre continues to occur with this increased pressure, a loading block that fits between the rim flanges and simulates the load transfer of the inflated tyre may be used. The arc of wheel supported by the loading block must be no greater than 60 degrees.

The wheel must support the loads without failure for at least 3 seconds. Abrupt loss of load-carrying capability or fragmentation during the test constitutes failure.

3.2.3 Wheel Roll Test.

3.2.3.1 Test Method.

With a suitable tyre, TT_{WT}, installed, mount the wheel on its axle and position it against a flat non-deflecting surface or a flywheel. The wheel axle must have the same angular orientation to the non-deflecting surface that it will have to a flat runway when it is mounted on an aeroplane and is under the Wheel Rated Static Load, S. During the roll test, the tyre pressure must not be less than 1.14 times the Wheel Rated Inflation Pressure, WRP, (0.10 to account for temperature rise and 0.04 to account for loaded tyre pressure). For side load conditions, the wheel axle must be yawed to the angle that will produce a wheel side load component equal to 0.15 S while the wheel is being roll tested.

3.2.3.2 Roll Test.

The wheel must be tested under the loads and for the distances shown in Table 3-1.

TABLE 3-1 Load Conditions and Roll Distances for Roll Test

Load Conditions	Roll Distance Miles (km)
Wheel Rated Static Load, S	2000 (3220)
Wheel Rated Static Load, S plus 0.15 S side load applied in the outboard direction	100 (161)
Wheel Rated Static Load, S plus 0.15 S side load applied in the inboard direction	100 (161)

At the end of the test, the wheel must not be cracked, there must be no leakage through the wheel or past the wheel seal(s), and the bearing cups must not be loose.

3.2.4 Roll-on-Rim Test (not applicable to nose-wheels).

The wheel assembly without a tyre must be tested at a speed of no less than 9 knots under a load equal to the Wheel Rated Static Load, S. The test roll distance (in feet) must be determined as $0.5V_R^2$ (V_R in knots) but need not exceed 15,000 feet (4572 meters). The test axle angular orientation with the load surface must represent that of the aeroplane axle to the runway under the static load S.

The wheel assembly must support the load for the distance defined above. During the test, no fragmentation of the wheel is permitted; cracks are allowed.

3.2.5 Overpressure Test.

The wheel assembly, with a suitable tyre, TT_{WT}, installed, must be tested to demonstrate that it can withstand the application of 4.0 times the wheel rated inflation pressure. WRP The wheel must retain the pressure for at least 3 seconds. Abrupt loss of pressure containment capability or fragmentation during the test constitutes failure. Plugs may be used in place of overpressurisation protection device(s) to conduct this test.

3.2.6 Diffusion Test.

A tubeless tyre and wheel assembly must hold its rated inflation pressure, WRP, for 24 hours with a pressure drop no greater than 5 percent. This test must be performed after the tyre growth has stabilised.

3.3 WHEEL AND BRAKE ASSEMBLY TESTS.

3.3.1 General.

3.3.1.1 The wheel and brake assembly, with a suitable tyre, TT_{BT}, installed, must be tested on a testing machine in accordance with the following, as well as paragraphs 3.3.2, 3.3.3, 3.3.5 and, if applicable, 3.3.4.

3.3.1.2 For tests detailed in paragraphs 3.3.2 , 3.3.3 and 3.3.4, the test energies KE_{DL}, KE_{RT}, and KE_{SS} and brake application speeds V_{DL}, V_{RT}, and V_{SS} are as defined by the aeroplane manufacturer.

3.3.1.3 For tests detailed in paragraphs 3.3.2, 3.3.3 and 3.3.4, the initial brake application speed must be as close as practicable to, but not greater than, the speed established in accordance with paragraph 3.3.1.2, with the exception that marginal speed increases are allowed to compensate for brake pressure release permitted under paragraphs 3.3.3.4 and 3.3.4.4. An increase in the initial brake application speed is not a permissible method of accounting for a reduced (i.e. lower than ideal) dynamometer mass. This method is not permissible because, for a target test deceleration, a reduction in the energy absorption rate would result, and could produce performance different from that which would be achieved with the correct brake application speed. The energy to be absorbed during any stop must not be less than that established in accordance with paragraph 3.3.1.2 Additionally, forced air or other artificial cooling means are not permitted during these stops.

3.3.1.4 The brake assembly must be tested using the fluid (or other actuating means) specified for use with the brake on the aeroplane.

3.3.2 Design Landing Stop Test.

3.3.2.1 The wheel and brake assembly under test must complete 100 stops at the KE_{DL} energy, each at the mean deceleration, D, defined by the aeroplane manufacturer, but not less than 10 ft/s^2 (3.05 m/s^2).

3.3.2.2 During the design landing stop test, the disc support structure must not be changed if it is intended for reuse, or if the wearable material is integral to the structure of the disc One change of individual blocks *or integrally bonded wearable material is permitted. For discs using integrally bonded wearable material, one change is permitted, provided that the disc support structure is not intended for reuse. The remainder of the wheel/brake assembly parts must withstand the 100 KE_{DL} stops without failure or impairment of operation

3.3.3 Accelerate-Stop Test.

3.3.3.1 The wheel and brake assembly under test must complete the Accelerate-Stop test at the mean deceleration, D, defined by the aeroplane manufacturer, but not less than 6 ft/s^2 (1.83 m/s^2).

This test establishes the maximum takeoff energy rating, KE_{RT}, of the wheel and brake assembly using:

a. The Brake Rated Maximum Operating Pressure, $BROP_{MAX}$; or

b. The maximum brake pressure consistent with the aeroplane's braking pressure limitations (e.g., tyre/runway drag capability based on substantiated data).

3.3.3.2 For the accelerate-stop test, the tyre, wheel, and brake assembly must be capable of absorbing the test energy, KE_{RT}, using a brake on which the usable wear range of the heat sink has already been fully consumed.

The proportioning of wear through the brake for the various friction pairs for this test must be based on service wear experience or wear test data of an equivalent or similar brake. Either operationally worn or mechanically worn brake components may be used. If mechanically worn components are used, it must be shown that they can be expected to provide similar results to operationally worn components. The test brake must be subjected to a sufficient number and type of stops to ensure that the brake's performance is representative of in-service use; at least one of these stops, with the brake near the fully worn condition, must be a Design Landing Stop.

3.3.3.3 At the time of brake application, the temperatures of the tyre, wheel, and brake, particularly the heat sink, must, as closely as practicable, be representative of a typical in-service condition. Preheating by a taxi stop(s) is an acceptable means.

These temperatures must be based on a rational analysis of a braking cycle, taking into account a typical brake temperature at which an aeroplane may be dispatched from the ramp, plus a conservative estimate of heat sink temperature change during subsequent taxiing, and takeoff acceleration, as appropriate.

Alternatively, in the absence of a rational analysis, the starting heat sink temperature must be that resulting from the application of 10 % KE_{RT} to the tyre, wheel and brake assembly initially at not less than normal ambient temperature (59°F/15°C).

3.3.3.4 A full stop demonstration is not required for the worn brake accelerate-stop test The test brake pressure may be released at a test speed of up to 20 knots. In this case. the initial brakes-on speed must be adjusted such that the energy absorbed by the tyre, wheel and brake assembly during the test is not less than the energy absorbed if the test had commenced at the specified speed and continued to zero ground speed.

3.3.3.5 Within 20 seconds of completion of the stop, or of the brake pressure release in accordance with paragraph 3.3.3.4, the brake pressure must be adjusted to the Brake Rated Maximum Parking Pressure $BRPP_{MAX}$ and maintained for 3 minutes.

No sustained fire that extends above the level of the highest point of the tyre is allowed before 5 minutes have elapsed after application of parking brake pressure; until this time has elapsed, neither fire fighting means nor coolants may be applied.

The time of initiation of tyre pressure release (e.g., by wheel fuse plug), if applicable, is to be recorded. The sequence of events described in paragraphs 3.3.3.4 and 3.3.3.5 is illustrated in Figure 3-1.

3.3.4 Most Severe Landing Stop Test.

3.3.4.1 The wheel and brake assembly under test must complete the most severe landing braking condition expected on the aeroplane as defined by the aeroplane manufacturer. This test is not required if the testing required by paragraph 3.3.3 is more severe or the condition is shown to be extremely improbable by the aeroplane manufacturer.

This test establishes, if required, the maximum energy rating, KE_{SS}, of the wheel/brake assembly for landings under abnormal conditions using:

a. The Brake Rated Maximum Operating Pressure, $BROP_{MAX}$; or

b. The maximum brake pressure consistent with an aeroplane's braking pressure limitations (e.g., tyre/runway drag capability based on substantiated data).

3.3.4.2 For the Most Severe Landing Stop test, the tyre, wheel and brake assembly must be capable of absorbing the test energy, KE_{SS}, with a brake on which the usable wear range of the heat sink has already been fully consumed.

The proportioning of wear through the brake for the various friction pairs for this test must be based on service wear experience or wear test data of an equivalent or similar brake. Either operationally worn or mechanically worn brake components may be used. If mechanically worn components are used, it must be shown that they can be expected to provide similar results to operationally worn components. The test brake must be subjected to a sufficient number and type of stops to ensure that the brake's performance is representative of in-service use; at least one of these stops, with the brake near the fully worn condition, must be a Design Landing Stop.

3.3.4.3 At the time of brake application, the temperatures of the tyre, wheel, and brake, particularly the heat sink, must, as closely as practicable, be representative of a typical in-service condition. Preheating by a taxi stop(s) is an acceptable means.

These temperatures must be based on a rational analysis of a braking cycle, taking into account a typical brake temperature at which the aeroplane may be dispatched from the ramp, plus a conservative estimate of heat sink temperature change during taxi, takeoff, and flight, as appropriate.

Alternatively, in the absence of a rational analysis, the starting heat sink temperature must be that resulting from the application of 5% KE_{RT} to the tyre, wheel and brake assembly initially at not less than normal ambient temperature (59°F/15°C).

3.3.4.4 A full stop demonstration is not required for the most severe landing-stop test. The test brake pressure may be released at a test speed of up to 20 knots. In this case, the initial brakes-on speed must be adjusted such that the energy absorbed by the tyre, wheel, and brake assembly during the test is not less than the energy absorbed if the test had commenced at the specified speed and continued to zero ground speed.

3.3.4.5 Within 20 seconds of completion of the stop, or of the brake pressure release in accordance with paragraph 3.3.4.4, the brake pressure must be adjusted to the Brake Rated Maximum Parking Pressure, $BRPP_{MAX}$, and maintained for 3 minutes.

No sustained fire that extends above the level of the highest point of the tyre is allowed before 5 minutes have elapsed after application of parking brake pressure; until this time has elapsed, neither fire fighting means nor coolants may be applied.

The time of initiation of tyre pressure release (e.g., by wheel fuse plug), if applicable, is to be recorded. The sequence of events described in paragraphs 3.3.4.4 and 3.3.4.5 is illustrated in Figure 3-2.

3.3.5 Structural Torque Test.

The wheel/brake rated structural torque (STR) is equal to the torque demonstrated in the test defined in paragraph 3.3.5.1.

3.3.5.1 Apply to the wheel, brake and tyre assembly, the radial load S and the drag load corresponding to the torque specified in paragraph 3.3.5.2 or 3.3.5.3 , as applicable, for at least 3 seconds. Rotation of the wheel must be resisted by a reaction force transmitted through the brake, or brakes, by the application of at least Brake Rated Maximum Operating Pressure, $BROP_{MAX}$, or equivalent. If such pressure or its equivalent is insufficient to prevent rotation, the friction surface may be clamped, bolted, or otherwise restrained while applying the pressure. A fully worn brake configuration, BRWL, must be used for this test. The proportioning of wear through the brake for the various friction pairs for this test must be based on service wear experience of an equivalent or similar brake or test machine wear test data. Either operationally worn or mechanically worn brake components may be used.

3.3.5.2 For landing gear with one wheel per landing gear strut, the torque is 1.2 (SxR)

3.3.5.3 For landing gear with more than one wheel per landing gear strut, the torque is 1.44 (SxR).

3.3.5.4 The wheel and brake assembly must support the loads without failure for at least 3 seconds.

3.4 BRAKE TESTS.

It must be substantiated that standard production samples of the brake will pass the following tests:

3.4.1 Yield and Overpressure Test.

The brake must withstand a pressure equal to 1.5 times BRP_{MAX} for 5 minutes without permanent deformation of the structural components under test.

The brake, with actuator piston(s) extended to simulate a maximum worn condition, must. for at least 3 seconds, withstand hydraulic pressure equal to two times the brake rated maximum pressure, BRP_{MAX}, available to the brakes. If necessary, piston extension must be adjusted to prevent contact with retention devices during this test

3.4.2 Endurance Test.

A brake assembly must be subjected to an endurance test during which structural failure or malfunction must not occur. If desired. the heat sink components may be replaced by a reasonably representative dummy mass for this test.

The test must be conducted by subjecting the brake assembly to 100,000 cycles of an application of the average of the peak brake pressures needed in the Design Landing Stop Test (paragraph 3.3.2) and release to a pressure not exceeding the brake rated return pressure, BRP_{RET}. The pistons must be adjusted so that 25,000 cycles are performed at each of the four positions where the pistons would be at rest when adjusted to nominally 25, 50, 75 and 100% of the wear limit, BRWL. The brake must then be subjected to 5000 cycles of application of pressure to BRP_{MAX} and release to BRP_{RET} at the 100% wear limit.

Hydraulic brakes must meet the leakage requirements of paragraph 3.4.5 at the completion of the test.

3.4.3 Piston Retention.

The hydraulic pistons must be positively retained without leakage at 1.5 times BRP_{MAX} for ten seconds with the heat sink removed.

3.4.4 Extreme Temperature Soak Test.

The brake actuation system must comply with the dynamic leakage limits of paragraph 3.4.5.2 for the following tests.

Subject the brake to a 24-hour hot soak at the maximum piston housing fluid temperature experienced during the Design Landing Stop Test (paragraph 3.3.2), conducted without forced air cooling. While at the hot soak temperature, the brake must be subjected to the application of the average of the peak brake pressures required during the 100 design landing stops and release to a pressure not exceeding BRP_{RET} for 1000 cycles, followed by 25 cycles of $BROP_{MAX}$ and release to a pressure not exceeding BRP_{RET}.

The brake must then be cooled from the hot soak temperature to a cold soak temperature of -40°F (-40°C) and maintained at this temperature for 24 hours. While at the cold soak temperature, the brake must be subjected to the application of the average of the peak brake pressures required during the KE_{DL} stops and release to a pressure not exceeding BRP_{RET}, for 25 cycles, followed by 5 cycles of $BROP_{MAX}$ and release to a pressure not exceeding BRP_{RET}.

3.4.5 Leakage Tests (Hydraulic Brakes).

3.4.5.1 Static Leakage Test.

The brake must be subjected to a pressure equal to 1.5 times BRP_{MAX} for 5 minutes. The brake pressure must then be adjusted to an operating pressure of 5 psig (35 kPa) for 5 minutes. There must be no measurable leakage (less than one drop) during this test.

3.4.5.2 Dynamic Leakage Test.

The brake must be subjected to 25 applications of BRP_{MAX}, each followed by the release to a pressure not exceeding BRP_{RET}. Leakage at static seals must not exceed a trace. Leakage at moving seals must not exceed one drop of fluid per each 3 inches (76mm) of peripheral seal length.

CHAPTER 4
DATA REQUIREMENTS.

4.1 The manufacturer must provide the following data with any application for approval of equipment.

4.1.1 The following wheel and brake assembly ratings:

a. Wheel Ratings.

Wheel Rated Static Load, **S**.
Wheel Rated Inflation Pressure, **WRP**.
Wheel Rated **Tyre** Loaded Radius, **R**.
Wheel Rated Maximum Limit Load, **L**.
Wheel Rated **Tyre** Size, TS_{WR}.

b. Wheel/Brake and Brake Ratings.

Wheel/Brake Rated Design Landing Energy, KE_{DL}, and associated **brakes-on-speed**, V_{DL}.
Wheel/Brake Rated Accelerate-Stop Energy, KE_{RT}, and associated brakes-on-speed, V_{RT}.
Wheel/Brake Rated Most Severe Landing Stop Energy, KE_{SS}, and **associated** brakes-on-speed, V_{SS} (if applicable).
Brake Rated Maximum Operating Pressure, $BROP_{MAX}$.
Brake Rated Maximum Pressure, BRP_{MAX}.
Brake Rated Retraction Pressure, BRP_{RET}.
Wheel/Brake Rated Structural Torque, ST_R.
Rated Design Landing Deceleration, D_{DL}.
Rated Accelerate-Stop Deceleration, D_{RT}.
Rated Most Severe Landing Stop Deceleration, D_{SS} (if applicable).
Brake Rated **Tyre** Size, TS_{BR}.
Brake Rated Wear Limit, **BRWL**.

4.1.2 The weight of the wheel or brake, as applicable.

4.1.3 Type of hydraulic fluid used, as applicable.

4.1.4 One copy of the test report showing compliance with the test requirements.

NOTE: When test results are being recorded for incorporation in the compliance test **report**, it is not **sufficient** to note merely that the specified performance was **achieved**. The actual numerical values obtained for each of the parameters tested must be **recorded**, except where tests are pass/fail in character.

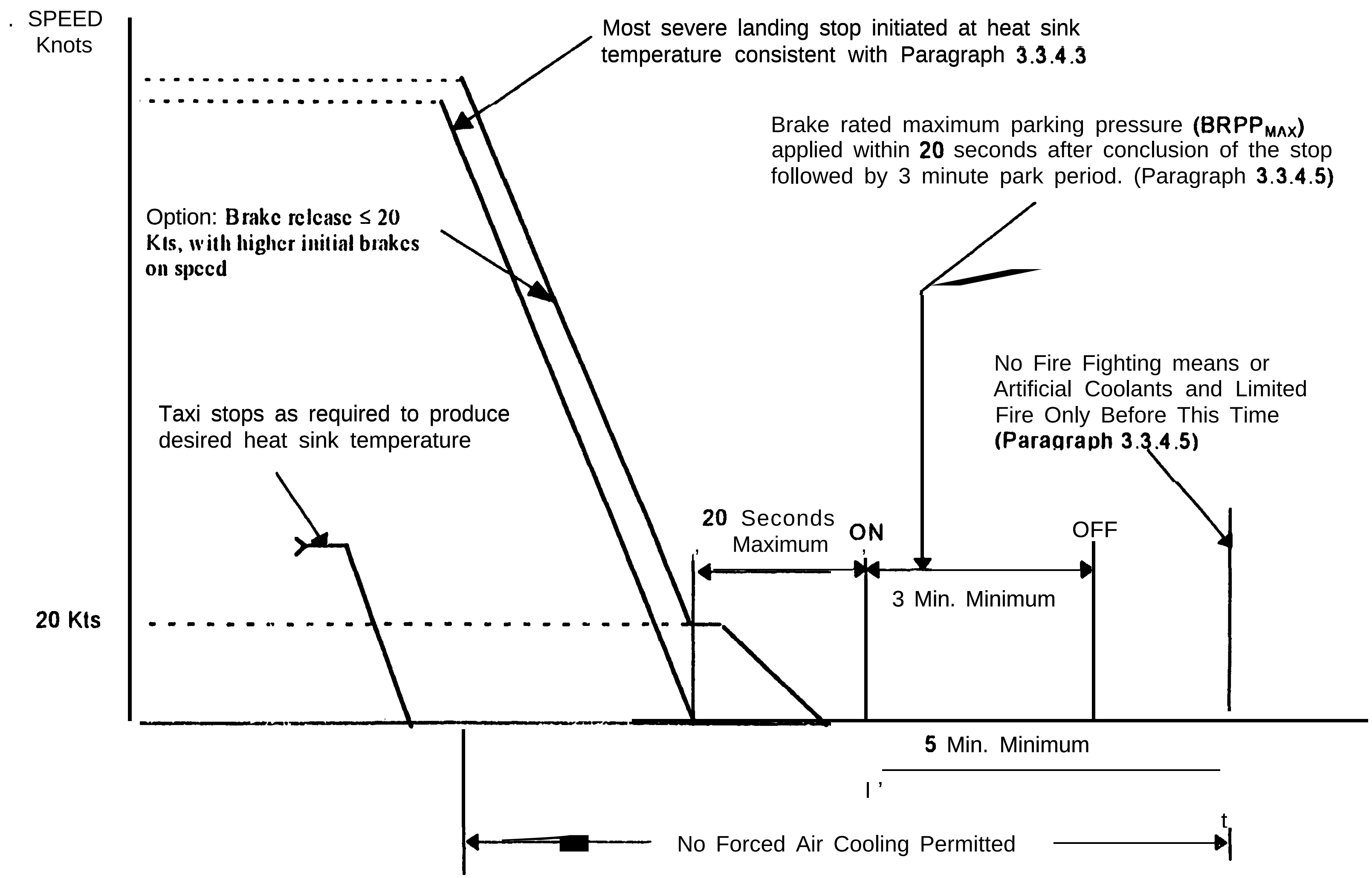

Figure 3-2 - Most Severe landing-Stop, Park lest Sequence